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A FIRST-TERM ATTRITION SEVERITY INDEX FOR U. S. NAVY RATINGS.(U)

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THESIS

A FIRST-TERM ATTRITION SEVERITY INDEX
FOR U. S. NAVY RATINGS

by

Patricia Griffin

June 1981

Thesis Advisor: George W. Thomas

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The purpose of this thesis was the development of a first-term attrition severity index for 85 United States Navy enlisted ratings. The multiattribute model utilized in the development of the index was constructed using five rating-specific factors: 1) attrition, 2) replacement cost, 3) size (number of personnel in the rating), 4) shortage or excess of billet requirements, and 5) priority. The model provided first-term attrition severity indicators for the 85 ratings included

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A First-Term Attrition Severity Index for U. S. Navy Ratings

by

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Lieutenant Commander, United States Navy
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Submitted in partial fullfillment of the requirements for the degree of

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ABSTRACT

The purpose of this thesis was the development of a first-term attrition severity index for 85 United States Navy enlisted ratings. The multiattribute model utilized in the development of the index was constructed using five rating-specific factors: 1) attrition, 2) replacement cost, 3) size (number of personnel in the rating), 4) shortage or excess of billet requirements, and 5) priority. The model provided first-term attrition severity indicators for the 85 ratings included in the study, indicating the diverse impact of attrition across Navy ratings and providing a practical basis for assigning scarce manpower resources to enlisted ratings experiencing the most severe effects of first-term attrition.

TABLE OF CONTENTS

LIST OF TABLES

I. INTRODUCTION

The excessive loss of skilled enlisted personnel from the United States Navy has been a major manpower issue for the past several years. The problem is even more critical today when the Navy, as well as all the other military services, is facing a shrinking pool of possible accessions. Moreover, in the face of continuing efforts to reduce military personnel expenditures, the costs associated with recruiting and training large numbers of personnel to fill the vacancies created by those who leave the Navy have become a matter of great concern. In addition to such supply and cost considerations, the excessive loss of valuable manpower resources makes it difficult to build and maintain a force with the desired skill and proficiency levels required to maintain operational effectiveness. The issue of excessive loss of skilled enlisted manpower is an important one which must receive continued attention if the Navy is to meet its increased force objectives projected for the 1980's.

One way in which the Navy loses enlisted personnel is through attrition. Attrition is normally defined as the failure of an individual to complete his or her current term of enlistment due to a variety of reasons including misconduct, inaptitude, family hardship, desertion, and physical or psychological disqualification. In this context, the Navy has sought to reduce attrition while at the same time develop an effective means for lessening the adverse effects of attrition when it does occur.

The purpose of this thesis is to develop an attrition severity index for those individuals serving on their initial enlistment, across

Navy ratings or occupational specialties. Such an index is of potential value to the Navy in reducing the adverse impact of the loss of personnel through attrition by providing an empirical basis for assigning scarce manpower inputs to the ratings identified as experiencing the most severe effects of first-term attrition. The use of the index in conjunction with other decision support models could be of significant value to the Navy in minimizing the impact of personnel losses.

The first step in developing a first-term attrition severity index is the identification of a set of factors or attributes which can be used to determine the severity of attrition. Five factors having a significant impact on rating-specific first-term attrition were identified: 1) survival, 2) replacement cost, 3) size, 4) shortage or excess of requirements, and 5) priority or importance. The impact of each of these factors on attrition is straightforward. For example, if a specific rating was experiencing low survival due to high attrition among its members, had a high cost of replacing the individuals who attrited, was experiencing severe shortages in manpower, and was of critical importance to the Navy in meeting its mission requirements, it would be reasonable to categorize the rating among those experiencing very severe attrition. On the other hand, if a rating demonstrated a high rate of survival, a low replacement cost, was small in size, had an excess of personnel, and was not of critical importance to the Navy, such a rating could reasonably be categorized among those experiencing low attrition severity. In yet another case, a rating might have a low survival rate, a moderate replacement cost, be small in size, have neither a shortage nor excess of manpower, and be relatively important

to the Navy. Such a rating could not be as easily categorized in a high or low attrition severity group and perhaps would be best categorized somewhere between the extreme ends of the scale.

After rating-specific numerical measures are obtained for each of the five factors under consideration, a multiattribute model is used to provide a single rating-specific index value which indicates first-term attrition severity. The use of a multiattribute model to determine the severity of attrition is based on two important observations. The first is that the numerical measures developed for each of the factors vary significantly across ratings. The second is that no single factor can provide an accurate measure of attrition severity, but rather such a measure must be obtained from combining the five factors considered.

The next chapter of the thesis will present a review of the work which has been conducted in the area of first-term attrition. Chapters three and four will present the development of rating-specific measures of survival and replacement cost, respectively. Chapter five will present the development of rating-specific measures of size, shortage or excess of requirements, and priority. Finally, the construction of a multiattribute model which will provide an index of first-term attrition severity for Navy ratings will be presented in chapter six.

II. LITERATURE REVIEW

The purpose of this chapter is to review briefly research which has been accomplished in the area of first-term attrition.

A. FIRST-TERM ATTRITION LITERATURE REVIEW

Due to the increased concern which has been expressed regarding the ability of the military services to man their ranks with the quantity and quality of individuals necessary to meet force objectives, an enormous amount of research in the area of attrition, particularly among first-term enlisted personnel, has been accomplished during the last decade. To varying degrees of magnitude, the results of this research have established relationships between attrition and a wide variety of factors including organizational climate and practices, job content, attitudes and satisfaction, intentions, expectations, and demographic and biographic characteristics. The focus of the literature presented in this section centers around studies completed within the past ten years pertaining to the first-term attrition behavior of Navy personnel. Although the studies presented do not represent an exhaustive review of all research which has been accomplished, they do provide a representative sample of the type and focus of the work which has been completed. More extensive reviews of the literature pertaining to the subject of attrition, not only in regard to the United States Navy but all the military services as well as foreign military organizations, have been completed by Hand, Griffeth, and Mobley (1977), Goodstadt and Yedlin (1979), and Wiskoff, Atwater, Houle, and Sinaiko (1980).

Table 1 provides an abridged summary of the studies reviewed in the area of first-term attrition. The overwhelming majority of the studies center around the use of preservice demographic and biographic variables, such as age, sex, education, mental ability, race, and marital or dependency status, to predict or explain attrition among Navy enlisted personnel.

Lockman (1978) developed a linear regression model for predicting first-year losses for Navy enlisted men using preservice characteristics. The cohort data used in the development of the model contained 66,680 nonprior service males, entering the Navy during calendar year 1973. The model predicted extremely well, accounting for 92% of the variance in aggregate first-year attrition. The preservice variables used to explain losses were mental ability, level of education, age at entry, race, and dependent status. The results obtained indicated that the higher mental groups, categories I and II, had lower attrition, while the lower mental groups, categories III-lower and IV, had higher attrition. Minorities were found to have lower attrition than caucasians, while individuals having dependents had higher attrition than those having no dependents. For the education variables, individuals with less than 12 years of education had higher attrition, while greater than 12 years of education entered the regression equation with a negative coefficient. Age was found to significantly affect premature losses, also. Both 17 and 20 year old enlistees had higher attrition rates than did the other age groups.

Lockman and Lurie (1980), using a 1977 cohort containing approximately 68,000 United States Navy males, 15,000 United States Naval Reserve males,

TABLE 1

Summary of First-Term Attrition Literature

Author(s)	Analytical Method	Dependent Variable	Independent Variables	General Results
Daniel (1980)	Regression Correlation	18-Month Attrition	Family Relations Early Maturity Authority Figures Personal Competence Adaptability Vocational Maturity	Attrition was significantly related to the type of relationship the enlistee had with his parents and school personnel, early responsibilities, reading ability and interests, military expectations, and the racial attitude of his parents.
Gunderson (1979)	Percentage	First-Term Attrition	Sex Mental Ability Race Education Age Occupation	The impact of the variables studied on attrition varied over time, with education being the general exception. Education was found to be the most significant and consistent predictor of attrition.
LaRocco, Gunderson & Pugh (1975)	Discriminant Analysis	First-Term Attrition	Biographical Service History Performance Attitudes	Race, age, education, mental ability, performance marks, number of demotions, time spent at sea, school expulsions, satisfaction, number of individuals supervised, occupation, and training significantly affected attrition behavior.

TABLE 1 (Cont'd)

Summary of First-Term Attrition Literature

Author(s)	Analytical Method	Dependent Variable	Independent Variables	General Results
Lau (1979)	Regression Correlation Factor Analysis	First-Year Attrition	Demographic Characteristics Preservice Attitudes Expectations Organizational Climate Achievement Need Control Living Conditions Navy Life Job Characteristics	Attrition was found to be higher among enlistees offered voluntary separation options. Attrition rates also were higher for general detail personnel than for A-school personnel. Separation decisions were related to preservice demographic characteristics, family problems, attitudes toward the Navy formed at recruit training, and in-service discrepancies between expectations and experiences. Finally, it was found that the longer personnel remained in the Navy, work environment reasons for attrition increased while family and personal factors decreased.
Lockman (1978)	Regression	First-Year Attrition	Mental Ability Education Age Race Dependents	Caucasian enlistees with lower mental ability, less formal education, and who were 17 or 20 years of age at entry with dependents attrited at higher rates than others.

TABLE 1 (Cont'd)

Summary of First-Term Attrition Literature

Author(s)	Analytical Method	Dependent Variable	Independent Variables	General Results
Lockman & Lurie (1980)	Regression	First-Year Survival	Sex Education Mental Ability Age Dependents	Males and females exhibited a general pattern of decreasing chances of survival as mental level and education declined. Seventeen, 18, and 19 year olds had higher survival rates than older recruits. Survival chances for male recruits with dependents were greater than those of single recruits, while married women had lower chances of survival than women who were not married.
Lurie (1979)	Regression	Four-Year Survival	Mental Ability Education	A-school personnel survived at higher rates than general detail personnel. Mental ability and education variables differed in their impact on survival for A-school and general detail personnel.
Olson & Stumpf (1978)	Chi-Square T-Tests	Two-Year Attrition	Sex	Women attrited due to reasons of pregnancy and unsuitability, while men attrited due to unsuitability, misconduct, or desertion.

TABLE 1 (Cont'd)

Summary of First-Term Attrition Literature

Author(s)	Analytical Method	Dependent Variable	Independent Variables	General Results
Sands (1976)	Regression	Four-Year Survival & Recommendation for Reenlistment	Mental Ability Education Expulsions & Suspensions	Individuals of higher mental ability, higher educational attainment, and who experienced fewer expulsions or suspensions from school survived and were recommended for reenlistment at higher rates than others.
Sands (1977)	Regression	Two-Year Survival	Mental Ability Education Age Dependents	Individuals of higher mental ability and higher educational attainment who were 17 years of age upon entry and did not have dependents survived at higher rates than others.
Thomason (1979)	Regression	Four-Year Survival	Age Race Dependents Location of Recruit Training Mental Ability Education Entry Program Duty Assignment	The preservice and in-service variables studied had differing impacts on survival behavior across different ratings and occupational groups.

TABLE 1 (Cont'd)

Summary of First-Term Attrition Literature

Author(s)	Analytical Method	Dependent Variable	Independent Variables	General Results
Thomason (1980)	Regression	Four-Year Survival	Age Education Site of Recruit Training Entry Program	By exploiting rating-specific preservice and in-service characteristics of enlistees, a 73% survival rate was estimated which was significantly higher than the actual rate of 63%.

and 4,500 United States Navy females, studied the survival of Navy recruits during the first year of service in an effort to determine if revision of the Success Chances of Recruits Entering the Navy (SCREEN) table, used by recruiters to screen applicants for enlistment, was necessary. The data were analyzed through the use of a multiple regression technique. For males as well as females, the results of the study indicated a general pattern of decreasing chances of survival as mental group and educational level declined. Additionally, it was found that 17, 18, and 19 year olds had higher survival rates than older recruits. Male and female survival rates were found to differ in the area of marital status. The survival chances for male recruits with dependents were greater than those of single recruits, while for women it was found that married females had lower chances of surviving the first year than women who were not married.

Sands (1976), using a sample of 364, nonprior service, male enlistees entering the Navy in 1960-1961, revised the Odds for Effectiveness (OFE) table used by recruiters to screen applicants for enlistment. The analysis was based on a multiple regression technique to predict recruit effectiveness. An effective recruit was defined as having completed a four-year term of enlistment and subsequently recommended for reenlistment. The predictors of effectiveness used in the study were mental ability, number of years of school completed, and number of expulsions or suspensions from school. The results of the study indicated that mental ability and level of education were positively related to effectiveness, while expulsions and suspensions were negatively related to effectiveness.

Sands (1977) in another study of attrition behavior used a sample of 68,616, nonprior service, enlisted males entering the Navy during calendar year 1973 to develop the Prediction of Enlisted Tenure - Two Year (Poet-2) model for the screening of enlistment applicants. The model was based on a multiple linear regression analysis. The data utilized in the prediction of two-year survival included mental aptitude, number of years of school completed, age at entry, and number of primary dependents. The results indicated that higher mental ability personnel exhibited higher survival rates, with one exception. Mental group IV personnel had higher survival rates than mental group III-lower enlistees. Furthermore, the results indicated that individuals who had attained higher levels of education survived at higher rates than those with lesser amounts of formal education. For age of entry, the author found that individuals enlisting at age 17 had a lower rate of survival than individuals 18 years of age or older. Enlistees with no primary dependents had a higher survival rate than those with one or more dependents.

Lurie (1979), using a 1973 Navy recruit cohort of four-year enlistees, studied recruit survival using two different methods, the Cox regression model and probit analysis. The analyses were performed separately for A-school and general detail personnel classified according to mental group and education with age, race, and the presence of primary dependents held constant. The results of the study generally indicated that A-school personnel exhibit more favorable survival profiles than general detail personnel. Additionally, general detail personnel exhibited relatively large attrition rates at a point approximately two months into their service in the Navy. Among general detail personnel, those with 12 years of education or more and classified in mental groups III-lower and

IV provided the highest survival profile, while those with less than 12 years of education and classified in mental groups I through III-upper provided the lowest profile over a four-year period. Among A-school personnel, those with 12 years of education or more, and classified in mental groups I through III-upper, provided the highest survival profile, while those with less than 12 years of education and classified in mental groups III-lower and IV provided the lowest profile. The Cox model, which uses cross-sectional data, and probit analysis, which requires cohort data, provided similar survival estimations.

Gunderson (1979) examined trends in first-term attrition in the Navy over a period of 12 years, 1965 through 1977. In exploring the overall male-female differences, Gunderson found that during the period of 1966-1968 women had an attrition rate of more than 50% within the first two years of service, compared to about 10% for men. Attrition rates for women sharply decreased from 1968 to 1974 while rates for men increased. For 1974 and 1975 accessions, the two-year attrition rate for men was slightly higher than for women, while attrition rates for men and women were the same for 1976 and 1977. A comparison of attrition rates among black and white enlistees was made by controlling level of education and mental ability. With education level equated, blacks consistently displayed higher attrition rates than whites, however, the differences were generally small. When mental ability was controlled, attrition was generally slightly greater for blacks. However, mental group IV blacks tended to have less attrition than mental group IV whites, and in 1977 blacks had less attrition than whites at all levels. Education was found to be the most significant predictor of attrition with high school

graduates generally having one-half the attrition rate of non-high school graduates. For the 1974-1976 period, 17-year old enlistees, both high school and non-high school graduates, had more attrition than older enlistees. The least attrition was seen for 18 and 19 year olds.

Gunderson also conducted a series of analyses on attrition rates for 12 occupational groups and six ratings. Using 1970-1972 as a baseline period prior to the all volunteer force, Gunderson found that four-year attrition was quite stable over the three-year period for most occupations and the differences among the occupational groups was not large. The highest attrition over the period was in the mess management specialist rating, and the next highest was seen in the hospital corpsman rating. The lowest attrition was seen in the boatswain's mate and communications ratings. The largest increase in attrition was in the boiler technician rating. During the 1973-1977 period there were slight increases in attrition rates for most occupations through 1975, followed by slight reductions in 1976 and 1977. There were a number of exceptions to the general rule, however. Engineering personnel showed sizable increases in attrition through 1975, particularly the boiler technician rating, and then slight decreases in 1976 and 1977. Additionally, the logistics group showed large increases. The author concluded from these findings that in addition to the general Navy-wide trends observed, there was some variability in how different occupational fields and ratings were affected.

Olson and Stumpf (1978) explored the effects of pregnancy on several dependent variables, including attrition. The sample for the

study consisted of approximately 821 first-term women and 872 first-term men, who had entered the Navy in the summer of 1975. The data used in the study were obtained through a survey administered in the summer of 1977 and longitudinal data obtained over the course of the cohort's first enlistment. The data were analyzed through the use of chi-square and t-tests. The results of the study indicated that attrition rates for women and men were the same at the end of the first two years of service, each group attriting approximately one-fourth of its members. However, the two groups differed substantially in their reasons for discharge. Pregnancy accounted for the greatest proportion of female discharges, approximately one-tenth of the original sample, followed by unsuitability. For males, unsuitability accounted for the greatest proportion of discharges, followed by misconduct or desertion. The proportion of women discharged for unsuitability was almost identical to that of men, 35% and 36% respectively; however, the proportion discharged for misconduct or desertion was much lower for women than for men, 4% and 17% respectively. Analysis of the survey data indicated that approximately one-half of the respondents would choose to leave the Navy if they became pregnant.

Not all of the studies utilizing preservice variables to predict attrition focused on demographic and biographic characteristics. Daniel (1980), using a questionnaire to obtain information concerning premilitary personal development and relationships with others from approximately 1,500 recruits entering the Navy in the latter part of 1977, developed a multiple regression model for predicting attrition and job performance among first-term enlistees. Six basic measures,

family relations, early maturity, personal competence, adaptability, vocational maturity, and authority figures, were used in the development of the predictive model. The results provided evidence that the model predicted attrition among first-term personnel in their first 18 months of service as effectively as did SCREEN scores.

Several significant results were forthcoming from the study. First, individuals who were at extremes, either very good or very bad, in their relationships with their parents and individuals whose parents were separated or divorced did not stay in or adjust well to the Navy. Individuals who had early responsibilities tended not to attrite as often as those who did not have such responsibilities. Attrition was related significantly to reading ability and interest, also. Individuals who indicated that they were good readers did not attrite as often as those who indicated otherwise. Persons who indicated that they read newspapers and science fiction also did not attrite as often as others. On the other hand, enlistees who were able to read when they entered the first grade and those who read nonfiction books tended to attrite more often than others. Furthermore, individuals whose parents had friends of a different race and were encouraged by their parents to have friends of a different race did not attrite as often as others. Persons who had a pattern of problems with school personnel prior to enlisting in the Navy tended to attrite more often than those who did not experience such problems. Finally, enlistees who joined the Navy with a set of definite expectations relating to the military service did not attrite as often as those who did not have such expectations.

Although the use of preservice characteristics has dominated the research conducted in the area of attrition behavior, in the last several years the impact of in-service characteristics on attrition also has been explored. In-service variables, such as site of recruit training or job assignment, are a result of experiences and situations encountered by an enlistee within the Navy organization, while preservice variables, such as level of education or age, are attributes an individual brings with him to the service. To varying degrees, the Navy can control both preservice and in-service variables, and, thus, an understanding of the impact of both types of variables on attrition as important in controlling the phenomena.

Lau (1979) attempted to determine the degree to which first-term enlisted attrition was the result of individual characteristics and organizational factors. The study was conducted utilizing a sample of 4,845 male, nonprior service, enlisted personnel who entered the Navy in November 1976. This sample included both those who were slated to attend apprenticeship training, which prepares individuals for general detail fleet assignments, and A-school, which prepares personnel for higher level tasks in an occupational rating. Approximately one-half of the personnel in the sample participated in an experimental voluntary release program while the other half served as a control group. All participants were surveyed upon completion of recruit training. The survey provided measures of demographic characteristics, preservice attitudes, expectations, organizational climate, general living conditions, achievement needs, and perceived control over events in their lives. Approximately seven months later, all individuals surviving in the sample were again surveyed, providing

measures of organizational structure and shipboard experience, expectations, organizational climate, job characteristics, and general living conditions. Finally, those in the experimental group who exercised the voluntary release option after they had reported to their first duty station assignment were surveyed providing measures of aspects of Navy life, expectations, organizational climate, and job characteristics. The data collected were analyzed using correlation, multiple regression, and factor analysis techniques.

Results of the study indicated that 27.4% of the experimental group attrited while less than 10% of the control group attrited during the first year of the study. A much higher percentage of the control group, 70%, reported that they definitely intended to complete their enlistment as compared to the experimental group, 41.5%. The author concluded that the voluntary separation option does influence attrition. Additionally, 38.3% of apprentice training personnel attrited compared to 23.8% of A-school personnel. The results of the study indicated that the perceptions of apprentice personnel were significantly lower than those of A-school personnel. The largest discrepancies between the two groups were found in training effectiveness, growth satisfaction, and experiences associated with the job itself. This finding is significant since the author found organizational climate and job perceptions were significantly correlated with intentions of completing the first enlistment and that intentions of completing the first enlistment were the best predictors of separation. Furthermore, the study provided evidence that the longer personnel remained in the Navy, environmental and job-related reasons for attrition increased while family or personal factors decreased. Generally, for all

those who attrited, separation decisions were found to be related to preservice demographic characteristics, family problems, attitudes toward the Navy formed in recruit training, and in-service discrepancies between expectations and actual experience.

LaRocco, Gunderson, and Pugh (1975) studied first-term attrition and reenlistment behavior among Navy personnel. The subjects of the study were 797 enlisted men whose first enlistments ended prior to July 1974. These men were part of a larger sample of 4,300 individuals who participated in a study of environmental and organizational effects on illness rates involving 20 ship from the Atlantic and Pacific fleets. The sample was divided into three groups: those recommended for reenlistment who actually reenlisted, those recommended for reenlistment who chose not to reenlist, and those who were not recommended for reenlistment or who were separated from the Navy prematurely. The questionnaires used to assess environmental and organizational characteristics included biographical information, service history data, and satisfaction measures, and were administered at the beginning of six-month overseas deployments. Only caucasian enlistees were included in the analysis. A step-wise discriminant analysis technique was used to analyze the data collected.

The results of the study indicated that those not recommended for reenlistment or discharged prematurely received the lowest performance marks, the most demotions, were the least satisfied, spent the fewest months at sea, received the fewest promotions, reported being expelled from school more often, and were the youngest of the three groups.

An even clearer picture of the differences among the three groups was obtained by examining the means of all the predictor variables

which were significant at the .01 level regardless of their contribution to the discriminant functions. The most striking aspect of the biographical domain was the prominence of school related variables. The results of the education variable showed that those who were not recommended for reenlistment or discharged prematurely had less education than both of the other groups. Additionally, a higher proportion of the reenlisting group reported being married than for the other two groups. Several service history variables also were found to be significant. The nonreenlisting group was found to have supervised the most men, while the group not recommended for reenlistment or discharged prematurely had supervised the fewest. The majority of those not recommended or discharged prematurely came disproportionately from the deck and engineering divisions, while those who reenlisted were the least likely to have come from these jobs. Reenlistees also were the most likely to have received technical training in their job specialties, while those not recommended or discharged prematurely the least likely. The mean mental ability scores of the reenlisting group were the highest, while the mean scores for the other two groups were almost identical.

Thomason (1979) estimated first-term survival rates for male enlisted personnel entering the Navy during calendar year 1973 and subsequently assigned to A-school. The 1973 cohort was tracked over four-years and survival rates estimated by applying the probit model to the longitudinal data obtained. Survival estimates were made for 14 different ratings or occupational groups, and the effects of age, race, dependent status, location of recruit training, mental ability, educational level, type of entry program, and type of duty assignment on each rating or occupational group were obtained.

The results of the analysis provided evidence that the characteristics studied did have a significant effect on four-year survival chances across ratings or occupational groups. Age was a significant factor in only five of the 14 ratings or groups studied. Recruits 17 years of age had lower survival chances for the machinist's mate rating, aviation maintenance group, health care group, and logistics group. Nineteen and 20 year old recruits had higher survival rates for boiler technicians and the logistics group. Education level had no effect on survival chances for six out of the 14 ratings or groups. The six unaffected groups were the machinist's mate rating, the sensor systems group, the electricians group, the radioman/communications group, the aviation weapons group, and the administration group. Education levels did affect survival rates in eight ratings or groups, and in virtually all cases the impact was strongly positive. Only one group, aviation maintenance, was positively affected by educational levels of above 12 years. Recruits who entered the service through the delayed entry program had higher survival rates than non-delay entry personnel in nine ratings or groups. The enlistee's recruit training location also affected his survival chances in nine ratings or groups. Recruit training in Orlando, Florida, was always at least as favorable to survival as training elsewhere. A recruit's race had an effect on his survival chances in only two rating groups. Noncaucasian recruits had a positive effect on survival in the health care group and a negative effect for the aviation maintenance group. Whether the new recruit had dependents affected his survival chances in only the boiler technician rating and the aviation support group.

In both of these groups the effect of dependents was negative. Lower mental group recruits were found to have survived at lower rates only in the boiler technician rating. However, in the aviation weapons group and the administration group, lower mental group recruits actually had higher survival rates than did other enlistees. Where activity or tour-type assignments affected survival, duty on an amphibious ship, an auxiliary patrol vessel, a surface combatant, or with a sea-based air squadron always had an adverse effect on survival, while assignment to a submarine or toured-sea duty always had a favorable impact. Only duty on an aircraft carrier had either a favorable or adverse effect depending on the rating or occupational group examined.

In a related study, Thomason (1980) explored the possibility of increasing first-term survival by exploiting rating-specific preservice and in-service characteristics of Navy enlisted personnel. First-term survival rates were estimated from 28,137 recruits who were enlisted in calendar year 1973 and served in 37 major ratings. Within the author's rating or occupational groupings, survival estimates were further disaggregated by age, level of education, site of recruit training, and type of entry program. An optimization model was applied to the data in order to maximize survival rates. This model was constrained in its reassignment of personnel to ratings by quantity and quality controls. The basic quantity control required all recruits to be assigned and all rating slots to be filled. The quality constraint required the assignment of personnel only to ratings for which they qualified by virtue of composite mental ability test scores.

The optimization model estimated a 73% first-term survival rate which was higher than the actual first-term rate of 67%. Generally, the most interesting specific results were the extremes. The solution placed no high school graduates in the engineman rating, no delayed entry recruits in the logistic ratings, and at least seven ratings received few, if any, individuals from one or even two of the three recruit training centers. Additionally, the model placed as many high school graduates as possible in six ratings or occupational groups: the boiler technician rating, electronic's technician/fire control technician group, aviation maintenance group, aviation support group, and medical group. However, high school graduates did not always survive at a higher rate in a given rating group than did non-high school graduates. In the logistics group, a delayed entry, non-high school graduate was approximately as likely to survive as a high school graduate who did not participate in the delayed entry program.

B. SUMMARY

The research which has been conducted in the area of first-term attrition clearly indicates the impact of a large number of variables on such behavior. The direction and magnitude of their impact, however, have been seen to vary among ratings or occupational groups. The work of Gunderson (1979) and Thomason (1979, 1980) have established rating-specific differences in a variety of preservice and in-service attributes. Additionally, Lau (1979) and LaRocco, Gunderson, and Pugh (1975) have established relationships between first-term attrition, and job-related and organizational variables. Considering the extent

to which job-related and organizational aspects of Navy life vary across ratings, such variables also may impact differently upon attrition among ratings.

More importantly, none of the studies reviewed has addressed exhaustive rating specific relationships. Of the more than 100 ratings used by the Navy, the most exhaustive studies have looked at no more than six specific ratings, aggregating most ratings into occupational groupings. Additionally, none of the studies reviewed has attempted to measure the severity of first-term attrition across Navy ratings. The purpose of this thesis is the development of first-term survival, cost, and demand data on an exhaustive partitioning of Navy ratings and the subsequent construction of a multiattribute model which combines these factors to form a first-term attrition severity index for U. S. Navy ratings.

III. SURVIVAL

The purpose of this chapter is to estimate the magnitude of rating-specific Navy losses through first-term attrition. One method of accomplishing this task is through the estimation of survival functions.

A. ESTIMATION OF SURVIVAL FUNCTIONS UTILIZING TRANSITIONAL WASTAGE RATES

The term "wastage" generally refers to the total loss of individuals from a system for any and all reasons. The system from which individuals are lost can be a large system, such as the U. S. Navy, or a subsystem of a larger system, such as a Navy rating. Perhaps the most natural way of investigating the pattern of wastage is to observe a homogeneous group or entrants, a cohort, and note how long each remains in the system before leaving. If data are available on all cohorts recruited in the past, a complete historical picture of the wastage process can be built. However, in reality it is often very difficult, if not impossible, to obtain extensive cohort data. Very few organizations maintain such data, but rather maintain data on stocks of individuals which aggregate cohorts within specified accounting periods. Nevertheless, because the data on stocks of individuals are comprised of cohorts of different ages, it is possible to reconstruct a composite picture of wastage rates and survival functions from this type of information.

When aggregate cohort data are available, several methods of estimating wastage rates can be applied to the information. One such method results in the construction of transitional or cross-sectional wastage rates. A transitional wastage rate ($\hat{w}$) is defined as:

$$\hat{w} = \frac{\text{Number of leavers during the accounting period among those in the system at the beginning of the accounting period}}{\text{Number in the system at the beginning of the accounting period}}$$

The primary weakness of the transitional wastage rate is its failure to account for inflows and outflows during the course of an accounting period. An individual may enter the system not at the beginning of the accounting period, but rather at some time during the accounting period. When utilizing transitional wastage rates to estimate loss rates, an individual entering and leaving the system during the course of the accounting period is not recognized as a leaver in the numerator of the equation nor as a member of the system in the denominator, and, thus, is not accounted for when estimating the transitional wastage rate. Since $1 - \hat{w}$ is an estimate of the transitional survival rate, survival rates also can be biased in the same manner.

B. ESTIMATION OF RATING-SPECIFIC SURVIVAL FUNCTIONS UTILIZING TRANSITIONAL WASTAGE RATES

Assuming an accounting period is equal to one year of service, let

S_i^j = the stock or number of individuals in the j^{th} Navy rating at the beginning of the i^{th} year of service for $i = 1,2,3,\ldots,n$ and j = ABE,ABF,ABH,...,YN

and let

$S_{i,k}^j$ = the stock or number of individuals in the j^{th} Navy rating at the beginning of the k^{th} year of service who were in the j^{th} rating at the beginning of the i^{th} year of service for $i = 1,2,3,\ldots,n$; $k \geq i$ and j = ABE,ABF,ABH,...,YN

It follows that

$$W_{i,k}^j = (S_i^j - S_{i,k}^j) \,/\, S_i^j \quad ; \quad \begin{array}{l} i = 1,2,3,\ldots,n \\ j = \text{ABE,ABF,ABH,...,YN} \end{array}$$

where, $W_{i,k}^j$ is the $(k - i)$ year wastage rate for individuals who were present in the j^{th} Navy rating at the beginning of the i^{th} year of service. If all individuals who lease a rating also leave the Navy, then $W_{i,i+1}^j$ is the i^{th} year attrition rate.

It would be preferable to be able to directly estimate yearly first-term attrition rates, $W_{1,k}^j$ for $k = 2,3,4,5$ for all Navy ratings. However, such estimations would involve tracking an entry cohort for a full four years. Alternatively, it is possible to utilize a cross sectional composition method for estimating first-term loss rates.

By looking at one year's data on each rating, a set of one-year transitional wastage rates, $W^j_{i,i+1}$ for i = 1,2,3,4 for first-term enlistees can be estimated. $1 - W^j_{i,i+1}$ can be interpreted as the probability that an individual in the j^{th} rating at the beginning of year i will continue in the j^{th} Navy rating to the beginning of the next year. Therefore, it follows that

$$P^j_{i,k} = \prod_{m=i}^{k-1} (1 - W^j_{m,m+1}) \quad ; \quad \begin{array}{l} i = 1,2,3,\ldots,n \\ k \geq i \\ j = \text{ABE,ABF,ABH},\ldots,\text{YN} \end{array}$$

where, $P^j_{i,k}$ is the probability an individual in the j^{th} Navy rating at the beginning of year i will continue to be in the j^{th} rating at the beginning of year k ($k \geq i$). Since the interest here is in first-term attrition, let

$$P^j_k = P^j_{1,k}$$

and

$P^j_1 = 1.00$, by definition.

One problem associated with the use of rating-specific transitional wastage rates is the creation of artificially high attrition rates. Laterally converted personnel create inaccuracies in the loss estimation attributed to specific ratings. Even though an individual may begin a year of service in one rating, he or she may convert to another rating during the course of a year. Thus, the loss of such an individual from a rating is counted as a loss from the Navy and enters the estimation of the attrition rate. A partial remedy for this problem is to consider an individual as a loss only if he or she is not in the Navy at the end

of a period as opposed to counting him or her as a loss if he or she is not in the same rating at the end of the period. Since the use of this method of accounting for losses provides a more accurate estimate of attrition rates, it will be used in calculating the survival functions presented in this chapter.

Another slight inaccuracy is introduced into the model through the assumption that S_1^j represents the stock or number of individuals in a specific rating on the first day of their service in the Navy. In reality, nonprior service accessions are not assigned to specific skill ratings immediately upon their entry into the Navy; rather, they are assigned to a number of apprenticeship ratings until they qualify for entry into a specific skill rating inventory. The length of time necessary for an individual to qualify for initial entry into a specific skill rating inventory varies across ratings and is a function of the training pipeline an individual pursues as a means of entering a technical rating.

In general, two distinct training pipelines are open to nonprior service accessions which lead to skilled rating designation. The first pipeline consists primarily of formal A-school training in a specific skill. After completion of initial recruit training approximately 70% of recruit training graduates immediately enter a formal A-school designed to provide training for a specific skill rating (Resource Consultants Incorporated, 1980). Upon completion of A-school, graduates immediately enter the technical rating inventory for which they received formal training. The length of time required for such an individual to enter a specific rating inventory is contingent

upon graduation and depends primarily on the length of A-school training. Since A-school course lengths vary among ratings and individual students, the times required to enter technical rating inventories via A-school also vary among ratings and individuals.

The second method of entering a technical rating inventory is through on-the-job training. After completion of recruit training, approximately 30% of recruit training graduates immediately enter formal apprentice training. These formal apprentice schools provide new recruits with basic skills in their designated apprenticeship areas. Upon completion of apprentice training, graduates enter the fleet and receive on-the-job training in a specific skill rating within their designated apprenticeship areas. When such an individual becomes eligible to take a Navy-wide examination for advancement to paygrade E-4, he is administered an examination for the rating in which he has received on-the-job training. If the individual passes the examination, he enters the specific technical rating inventory. The length of time required for such an individual to enter a technical rating inventory depends primarily on the time it takes such an individual to qualify to take an examination for possible advancement to paygrade E-4 and the number of times an individual takes an examination before he passes the test. Passing rates for Navy-wide advancement examinations also vary among ratings. From the foregoing discussion, it is apparent that the time required to initially enter a rating inventory differs across ratings and among individuals.

Since the majority of nonprior service accessions initially enter a rating inventory through the formal A-school pipeline, it can be

assumed that the majority of annual accessions initially enter a rating inventory within a relatively short period of time. Huck and Midlam (1977), using a 1976 data base, provided evidence that approximately 60% of new accessions at the six-month point in their first enlistments had attained a skilled rating status. Despite the apparent rapidity with which most new accessions enter Navy ratings, when survival functions are estimated for specific skill ratings, the effect of attrition which occurs prior to rating designation or while individuals are members of general apprenticeship ratings is not brought to bear. Evidence has been provided by Lurie (1979) that substantial attrition does occur among nondesignated personnel in the first few months of service, particularly among general detail personnel or those who are in the on-the-job training pipeline. Since nondesignated personnel are in general members of large apprenticeship ratings which cannot be uniquely identified with specific skill ratings, the full impact of attrition behavior among first-term personnel is not accurately captured by the model. Any rating-specific survival functions estimated using the model are based on the survival of individuals after reaching designated rating status.

1. <u>Data Base and Methodology</u>

The data base used to estimate rating-specific survival functions was the Navy Enlisted Master File. This file contains information on all active duty enlisted personnel in the U. S. Navy including information concerning the rating of individual members. The one-year cross-sectional data used to estimate rating-specific survival functions covered the period of September 30, 1979 to September 30, 1980.

Although four-year initial enlistments are considered to be the norm, depending on the magnitude of the guarantees of formal training contained in initial enlistment contracts, it is not unusual to find some individuals enlisting for five or six years. Consequently, the data were screened by rating to determine which ratings contained substantial numbers of first-term personnel whose initial enlistment obligations were five or six years in duration. Seventeen ratings were identified as containing a substantial number of individuals who had initially enlisted for six years. No ratings were found to have a substantial number of five-year enlistments. However, among the ratings which contained substantial numbers of six-year enlistees, the four-year enlistees by far exceeded the number of six-year obligors. Thus, for the purpose of this study, the typical first-term enlistee was considered to be serving in the Navy on an initial four-year enlistment obligation, and survival functions were estimated exclusively from data obtained on four-year obligors.

Including the apprenticeship ratings, 118 ratings were identified within the data base. However, all ratings are not open to first-term junior personnel due to the proficiency level or nature of the job to be performed by a member of the rating. These senior ratings are identified in Table 2 and were deleted from the study. Additionally, since the majority of the apprenticeship ratings could not be uniquely associated with a specified technical rating, these ratings also were deleted from the study. The exception was the medical apprenticeship ratings which could be uniquely identified with the hospital corpsman and dental technician ratings. The hospitalman recruit, hospitalman

TABLE 2

U. S. Navy Senior Ratings

Rating Abbreviation	Rating Name
AB	Aviation Boatswain's Mate
AF	Aircraft Maintenanceman
AM	Aviation Structural Mechanic
AS	Aviation Support Equipment Technician
AV	Avionics Technician
CU	Constructionman
EQ	Equipmentman
FT	Fire Control Technician
GM	Gunner's Mate
GS	Gas Turbine System Technician
LN	Legalman
MA	Master-At-Arms
NC	Navy Counselor
PI	Precision Instrumentman
ST	Sonar Technician

apprentice, and hospitalman ratings exclusively provide manpower inputs to the hospital corpsman rating, while the dentalman recruit, dentalman apprentice, and dentalman ratings exclusively feed the dental technician rating. These specific medical apprenticeship ratings were combined with the appropriate technical medical rating to derive the stocks for the computation of survival rates. Table 3 identifies all the apprenticeship ratings and Table 4 identifies the 85 ratings ultimately used in the study.

2. Results

The survival functions resulting from the estimation procedure are presented in Table 5. Since the survival functions estimated for year four are biased by reenlistment behavior, the cumulative year three figure may present the best measure of first-term rating-specific survival. The issue of the best survival measure will be addressed in chapter VI. The year three figure represents the probability that an individual in a given rating will complete year three in the Navy after attaining designated rating status. The five ratings which were found to have the lowest year-three probabilities of survival were illustrator draftsman (.6028), opticalman (.6667), mess management specialist (.6937), ship's serviceman (.6963), and ocean systems technician (.7119). The highest probabilities of survival were found among the communications technician (interpretive) (.9455), missile technician (.9446), patternmaker (.9231), data systems technician (.9216), and aviation electrician's mate (.9194) ratings.

These findings are generally consistent with the demonstrated favorable impact of higher mental ability on aggregate first-term attrition

TABLE 3

U. S. Navy Apprenticeship Ratings

Rating Abbreviation	Rating Name
AR	Airman Recruit
AA	Airman Apprentice
AN	Airman
CR	Constructionman Recruit
CA	Constructionman Apprentice
CN	Constructionman
DR	Dentalman Recruit
DA	Dentalman Apprentice
DN	Dentalman
FR	Fireman Recruit
FA	Fireman Apprentice
FN	Fireman
HR	Hospitalman Recruit
HA	Hospitalman Apprentice
HN	Hospitalman
SR	Seaman Recruit
SA	Seaman Apprentice
SN	Seaman

TABLE 4

U. S. Navy Ratings Utilized in the Study

Rating Abbreviation	Rating Name
ABE	Aviation Boatswain Mate (Launching and Recovery)
ABF	Aviation Boatswain's Mate (Fuels)
ABH	Aviation Boatswain's Mate (Aircraft Handling)
AC	Air Controlman
AD	Aviation Machinist's Mate
AE	Aviation Electrician's Mate
AG	Aerographer's Mate
AK	Aviation Storekeeper
AME	Aviation Structural Mechanic (Safety Equipment)
AMH	Aviation Structural Mechanic (Hydraulics)
AMS	Aviation Structural Mechanic (Structures)
AO	Aviation Ordnanceman
AQ	Aviation Fire Control Technician
ASE	Aviation Support Equipment Technician (Electrical)
ASH	Aviation Support Equipment Technician (Hydraulics and Structures).

TABLE 4 (Cont'd)

U. S. Navy Ratings Utilized in the Study

Rating Abbreviation	Rating Name
ASM	Aviation Support Equipment Technician (Mechanical)
AT	Aviation Electronics Technician
AW	Aviation Antisubmarine Warfare Operator
AX	Aviation Antisubmarine Warfare Technician
AZ	Aviation Maintenance Administrationman
BM	Boatswain's Mate
BT	Boiler Technician
BU	Builder
CE	Construction Electrician
CM	Construction Mechanic
CTA	Communications Technician (Administrative)
CTI	Communications Technician (Interpretive)
CTM	Communications Technician (Maintenance)
CTO	Communications Technician (Communications)
CTR	Communications Technician (Collection)
CTT	Communications Technician (Technical)

TABLE 4 (Cont'd)

U. S. Navy Rating Utilized in the Study

Rating Abbreviation	Rating Name
DK	Disbursing Clerk
DM	Illustrator Draftsman
DP	Data Processing Technician
DS	Data Systems Technician
DT	Dental Technician
EA	Engineering Aid
EM	Electrician's Mate
EN	Engineman
EO	Equipment Operator
ET	Electronics Technician
EW	Electronics Warfare Technician
FTB	Fire Control Technician (Ballistic Missile Fire Control)
FTG	Fire Control Technician (Gun Fire Control)
FTM	Fire Control Technician (Surface Missile Fire Control)
GMG	Gunner's Mate (Guns)
GMM	Gunner's Mate (Missiles)
GMT	Gunner's Mate (Technician) (Electrical)

TABLE 4 (Cont'd)

U. S. Navy Ratings Utilized in the Study

Rating Abbreviation	Rating Name
GSM	Gas Turbine System Technician (Mechanical)
HM	Hospital Corpsman
HT	Hull Maintenance Technician
IC	Interior Communications Electrician
IM	Instrumentman
IS	Intelligence Specialist
JO	Journalist
LI	Lithographer
ML	Molder
MM	Machinist's Mate
MN	Mineman
MR	Machinery Repairman
MS	Mess Management Specialist
MT	Missile Technician
MU	Musician
OM	Opticalman
OS	Operations Specialist
OT	Ocean Systems Technician
PC	Postal Clerk

TABLE 4 (Cont'd)

U. S. Navy Ratings Utilized in the Study

Rating Abbreviation	Rating Name
PH	Photographer's Mate
PM	Patternmaker
PN	Personnelman
PR	Aircrew Survival Equipmentman
QM	Quartermaster
RM	Radioman
RP	Religious Program Specialist
SH	Ship's Serviceman
SK	Storekeeper
SM	Signalman
STG	Sonar Technician (Surface)
STS	Sonar Technician (Submarine)
SW	Steelworker
TD	Trademan
TM	Torpedoman's Mate
UT	Utilitiesman
YN	Yeoman

TABLE 5

Survival Functions for U. S. Navy Ratings

Rating	Survival Functions by Year of Service			
	1	2	3	4[b]
ABE	.9474	.9099	.8488	.1743
ABF	.9444	.9011	.8421	.2627
ABH	.9308	.8641	.8150	.2595
AC	.9652	.9316	.8953	.3891
AD	.9490	.9099	.8741	.2509
AE	.9926	.9538	.9194	.2620
AG	.9402	.8885	.8426	.3025
AK	.9045	.8236	.7583	.3211
AME	.9559	.9099	.8745	.2833
AMH	.9565	.8962	.8517	.2810
AMS	.9738	.9170	.8814	.2513
AO	.9361	.8916	.8289	.2724
AQ	.9206	.9007	.8444	.5282
ASE	.9500	.8972	.8510	.3695
ASH	.8772	.8368	.7858	.3066
ASM	.9091	.8548	.7922	.2296
AT	.9418	.9094	.8770	.5623
AW	.9333	.9040	.8674	.3858

TABLE 5 (Cont'd)

Survival Functions for U. S. Navy Ratings

Rating	Survival Functions by Year of Service			
	1	2	3	4[b]
AX	1.000	.9774	.9193	.6585
AZ	.9122	.8222	.7472	.2791
BM[a]	1.000	.9452	.8846	.2066
BT	.9057	.8225	.7563	.2228
BU	.9497	.9076	.8713	.6713
CE	.9808	.9118	.8560	.7289
CM	.9664	.9106	.8580	.6730
CTA	.9500	.8576	.7529	.3940
CTI[a]	1.000	1.000	.9455	.3546
CTM	.9737	.9303	.9102	.8649
CTO	.9265	.8695	.8380	.3343
CTR	.8769	.8392	.7910	.3333
CTT	.9706	.9310	.8637	.3684
DK	.9175	.8665	.8142	.3673
DM[a]	.6667	.6296	.6028	.3800
DP	.9543	.8947	.8380	.5797
DS[a]	1.000	.9708	.9216	.8229
DT	.9311	.8695	.8003	.6296
EA	.8889	.8672	.8053	.3451

TABLE 5 (Cont'd)

Survival Functions for U. S. Navy Ratings

Rating	Survival Functions by Year of Service			
	1	2	3	4[b]
EM	.9266	.8740	.8315	.3679
EN	.9183	.8570	.8015	.1892
EO	.9490	.8792	.8059	.6368
ET	.9401	.8884	.8366	.6500
EW	.9524	.9407	.9101	.6940
FTB[a]	1.000	.9050	.8524	.7926
FTG	.9444	.9040	.8687	.4234
FTM	.9263	.8906	.8228	.5494
GMG	.9242	.8547	.7947	.2289
GMM	.9714	.9063	.8267	.2179
GMT	.9359	.8978	.8643	.3602
GSE[a]	1.000	1.000	1.000	.7429
GSM[a]	1.000	.9552	.9054	.6700
HM	.9270	.8647	.8130	.3080
HT	.9383	.8689	.8111	.2209
IC	.9469	.8955	.8438	.3886
IM[a]	.9444	.8604	.8286	.2279
IS	.9362	.8771	.8505	.4160

TABLE 5 (Cont'd)

Survival Functions for U. S. Navy Ratings

Rating	Survival Functions by Year of Service			
	1	2	3	4[b]
JO	.9091	.8296	.7614	.4615
LI[a]	1.000	.9091	.8629	.3452
ML[a]	.8333	.8333	.7471	.1132
MM	.9071	.8428	.7783	.3481
MN	.9231	.8688	.8302	.4543
MR	.9829	.9132	.8739	.2125
MS	.8662	.7705	.6937	.2527
MT	1.000	.9804	.9446	.8943
MU[a]	1.000	.9592	.9098	.4072
OM[a]	1.000	.9286	.6667	.3250
OS	.9170	.8578	.8044	.2021
OT	.8493	.7738	.7119	.2949
PC	.9286	.8107	.7353	.1961
PH	.9712	.9324	.8831	.6943
PM[a]	1.000	.9231	.9231	.0462
PN	.8727	.7948	.7348	.3411
PR	.8716	.8192	.7914	.2416
QM	.9187	.8493	.8049	.2345

TABLE 5 (Cont'd)

Survival Functions for U. S. Navy Ratings

Rating	Survival Functions by Year of Service			
	1	2	3	4[b]
RM	.9031	.8316	.7800	.3292
RP[a]	.9444	.7870	.7555	.5288
SH	.8958	.7640	.6963	.1992
SK	.9282	.8600	.8113	.3012
SM	.8898	.7852	.7198	.1813
STG	.9495	.8776	.8230	.5738
SW	.9583	.9158	.8234	.6606
TD	.8437	.7852	.7701	.2950
TM	.9141	.8281	.7719	.3106
UT	.9048	.8643	.8172	.6425
YN	.8997	.8329	.7851	.3443

[a] Contains year of service cells which consist of less than 20 individuals.

[b] Survival estimations based on rating-specific losses resulting from attrition as well as failure to reenlist.

(Lockman, 1978; Lockman & Lurie, 1980; Sands, 1976, 1977). Table 6 provides a breakdown of enlisted ratings according to technical skill requirements. The categorization of ratings into semi-technical, technical, and highly technical groups was developed by the Deputy Chief of Naval Operations (Manpower, Personnel, and Training), and were based on the minimum qualifying test scores and the amount of formal training required to enter specific ratings. Four of the five ratings displaying the highest probabilities of survival are categorized as highly technical, while only one rating is categorized as technical. Conversely, among the five ratings providing the lowest probabilities of survival, two ratings are categorized as semi-technical and three as technical. The general association of mental ability with first-term attrition may provide a partial explanation for the wide range of survival functions estimated across Navy ratings.

TABLE 6

Technical Skill Requirements for U. S. Navy Ratings

Semi-technical		Technical					Highly Technical	
ABE	MS	AD	BU	EM	IS	PM	AC	ET
ABF	PC	AG	CE	EN	JO	PR	AE	EW
ABH	PN	AME	CM	EO	ML	QM	AQ	PTB
AK	RP	AMH	CTA	GMG	MM	RM	AT	FTG
BM	SH	AMS	CTO	GMM	MN	SW	AX	FTM
BT	SK	AO	CTR	GMT	MR	TM	CTI	MT
HT	SM	ASE	DK	GSE	MU	UT	CTM	STG
LI	YN	ASH	DM	GSM	OM		CTT	STS
		ASM	DP	HM	OS		DS	TD
		AW	DT	IC	OT			
		AZ	EA	IM	PH			

IV. REPLACEMENT COST

The purpose of this chapter is to review the type of cost data which are available that can be utilized in the construction of rating-specific replacement costs, as well as to develop measures for such costs. For the purpose of analyzing the impact of cost on attrition severity, a first-term replacement cost will be defined as the total cost to the U. S. Navy to replace an individual in a particular rating who attrites at a specified time of service prior to the completion of his or her first-term of enlistment. In the context of this definition, a simple and practical means of estimating replacement costs can be developed through the use of length of service and rating-specific cost data. In view of the foregoing, every effort was made to locate cost data of this nature to facilitate the development of replacement costs.

A. NAVY ENLISTED BILLET COST MODEL

The Navy Enlisted Billet Cost Model (BCM) was developed approximately 15 years ago, primarily as a means of addressing cost issues associated with force structure and manpower planning. Over the years it has been modified extensively in an attempt to enhance the economic soundness of its underlying cost concepts. Although weaknesses may exist in the model's methodology and some relevant cost considerations may be ignored entirely, it stands as the best and most comprehensive model currently available for estimating the economic cost of Navy enlisted manpower. A review of costing models currently used by the Navy provided no other

single source of costing data which could be used to approximate rating-specific first-term replacement costs. Although another model, the Per Capita Cost Model (PCM) which was designed to estimate the per capita cost of the average Navy enlisted member by rating, paygrade, and length of service, appears to be more applicable to the problem at hand, the PCM draws its cost data directly from selected BCM cost elements.

1. General Description

The complexity of the BCM and the many modifications made to the model over the past several years pose certain problems in any attempt to analyze the BCM. Analyses of the model conducted by Eskew, Berterman, Smith, Noah, and Breaux (1978), and Butler and Simpson (1980) were used to gain an insight into the model's output and the methods utilized in generating the output. These two basic sources of information provided not only a general description of the model but also a critical analysis of its fundamental concepts and recommendations for improving the quality of its output. The description of the model found in this section is based directly upon the analyses presented in the two studies and not upon an original investigation of the BCM.

The BCM was developed to provide the Navy with a means of computing reasonably accurate manpower resource costs. On the personnel side, the model recognizes that the Navy procures personnel resources, and, though training and experience, develops these resources into the skill levels required to perform the many and varied jobs within the Navy's organizational structure. In the enlisted area, these skills and skill levels are represented by ratings and paygrades. On the manpower side, the Navy identifies its enlisted manpower requirements in terms of billets, where a billet is defined as a unique combination of rating and

paygrade, such as a E-4 boiler technician billet. Within this personnel and manpower framework, the BCM computes the annual costs of manning authorized billets with personnel possessing requisite skills, in terms of investment and operational costs to the U. S. Government. Currently, the BCM provides cost data for 94 ratings and eight paygrades, E02 through E-9, within each rating.

The billet cost data provided by the model are of obvious use to the Navy in force and manpower planning. The BCM was designed to accomodate all types of costs, providing means of converting grade-specific costs to length of service costs and vice versa, as well as allocating overhead costs to paygrades and length of service cells. The model provides rating-specific costs as a function of either length of service or paygrade. The two methods are highly interrelated due to the differing structure of the basic cost elements utilized by the model. The length of service method is more useful for estimating first-term replacement costs.

The cost conversion and allocation procedures incorporated in the BCM are in many cases intricate and performed in a variety of ways. When it is necessary to convert costs by rating and length of service to costs by rating and paygrade, the conversion is typically performed using rating-specific median length of service data. For example, if the median length of service for an E-5 yeoman is 6.7 years, the cost associated with a yeoman in the seventh year of service is assigned to paygrade E-5. The conversion of rating and paygrade specific costs to rating and length of service specific costs is more complex and involves the application of rating-specific mean times to advancement. If, for example, the mean time to advancement to E-5 in a given rating is 4.3 years, the cost for year five is computed as:

.3 (Rating Cost for E-4) + .7 (Rating Cost for E-5)

Then, if the mean time to advancement to E-6 in the same rating is 10.6 years, the years six through ten are exclusively identified with paygrade E-6, and the costs for these years are simply the costs associated with paygrade E-6. For overhead costs which cannot be readily identified with a specific paygrade, length of service cell, or rating, annual per capita costs are computed and are transferred directly to length of service cells or distributed proportionally to paygrades on the basis of the size of the paygrade inventory. Overhead costs are typically distributed equally across ratings. Although the examples provided oversimplify the costing methods used in the BCM, they do provide a general description of the type of conversion and allocation techniques incorporated in the model.

2. <u>Cost Elements</u>

Ten basic cost elements are utilized by the BCM: 1) base pay, 2) hazard pay, 3) FICA, 4) all Navy cost by grade, 5) all Navy cost by year, 6) constant cost by grade, 7) constant cost by year, 8) retirement costs, 9) school costs, and 10) downtime costs.

a. Base Pay

The base pay cost element reflects an enlisted member's annual base pay or basic salary. The computed base pay costs are based on nonrating-specific statutory tables of monthly base pay by paygrade and length of service.

b. Hazard Pay

This BCM cost element consists of flight crew and submarine crew pay. Like base pay, hazard pay is calculated from statutory tables; however, hazard pay is calculated as a function of the probability of receiving hazard pay within specific ratings.

c. FICA

The FICA cost element recognizes the Navy's responsibility as an employer to contribute to Social Security. Under the federal statutes governing the Social Security system, both employers and employees are required to contribute equal amounts in the form of Social Security taxes. The FICA costs borne by the Navy and transferred to the U. S. Treasury are computed by multiplying an appropriate FICA rate by base pay and cannot exceed statutory ceilings placed on such contributions.

d. All Navy Costs by Grade

The all Navy costs by grade element includes those costs which are considered by the model not to be rating-specific, but rather are defined and allocated by paygrade. This basic cost element consists of nine individual components or subelements: 1) sea and foreign duty pay, 2) family separation allowance, 3) overseas station allowance, including cost of living, housing, and temporary lodging payments, 4) quarters allowance in cash, or the cash amount provided to an enlisted member for housing when government quarters cannot be furnished, 5) quarters allowance in kind, or the cost of providing an enlisted member with government quarters, 6) unemployment insurance, which reflects the Department of Labor's allocation of such costs to the Navy, 7) commissary, 8) medical and Civilian Health and Medical Program for the Uniform Services (CHAMPUS) costs, and 9) PCS, which includes accession, training, operational, rotational, separation, and organizational travel costs. Most of the cost estimates of the individual components are developed outside of the model, principally from current year budget data, and are provided as inputs to the model as paygrade-specific totals. For

subelements, such as commissary, overseas station allowance, and unemployment insurance, where the input data are provided as lump-sums and are not grade-specific, costs are allocated to paygrades as per capita costs.

e. All Navy Cost by Year

This category is similar to all Navy costs by grade by virtue of the fact that the costs which comprise the category are not rating-specific and are drawn primarily from budget data, but differs in the fact that the costs are considered by the model to vary by length of service. The all Navy cost by year element is composed of nine individual components: 1) accession clothing, reflecting the cost of the initial issue of uniforms to new recruits, 2) recruitment, including advertising and other explicit budget expenses associated with recruiting, 3) messing and subsistence, consisting of cash disbursements for food computed from a daily subsistence rate gleaned from budget data and multiplied by a 360-day year, 4) command and administration, composed of a variety of personnel related costs derived from budget data, 5) dependent schools, consisting of the costs associated with the operation of dependent schools in overseas locations, 6) E-7 clothing, recognizing the initial uniform allowance provided to newly selected chief petty officers, 7) death gratuity, including the costs associated with the death of active duty members, 8) prisoner apprehension, including the costs associated with the apprehension of deserters, and 9) disability provision, consisting of costs incurred when members are disabled on active duty. The costs associated with each component of the element are allocated to length of service cells based on the type of component in question. The costs associated with some subelements, such as

accession clothing, recruitment, and E-7 clothing, can be uniquely associated with a specific length of service cell. For example, accession clothing and recruitment costs are allocated entirely to the first year of service, while the E-7 clothing cost is allocated entirely to the length of service cell which corresponds to an E-7's mean time to advancement within a rating. Other component costs which cannot be uniquely identified with a specific length of service cell are allocated equally to all cells as annual per capita costs.

f. Constant Cost by Grade

This element was designed to include all grade-specific premium pays other than hazard pay. Currently, input data for this element are not available for use by the BCM; however, inputs from the Joint Unified Military Pay System (JUMPS) are anticipated in the future.

g. Constant Cost by Year

Currently, this element consists solely of selected reenlistment bonus (SRB) costs, or those costs associated with incentive bonuses paid to reenlisting first and second-term personnel. Selected reenlistment bonus costs are computed on the basis of rating-specific bonus eligibility and are distributed to length of service cells five through 20.

h. Retirement Costs

The BCM uses a complex algorithm for distributing anticipated retirement costs to a given paygrade and rating. A required retirement fund size is computed for every possible paygrade and length of service retirement window. For each such window a probability also is calculated that an individual will retire in that window rather than some other.

The products of these fund sizes and the probabilities are than discounted to present value and summed to yield current retirement liability. This allocation method treats retirement as an accrued liability and distributes retirement costs over length of service cells to form a sinking fund based upon the probability of reaching vesting points in each length of service cell.

i. School Costs

School costs are derived from the Navy Integrated Training Resource and Administration System (NITRAS) data base and are used to estimate marginal course costs. After these specific course costs have been estimated, course attendance records are reviewed and matched to the Navy's Enlisted Master File in order to develop specific rating and length of service data on course attendees. When this has been accomplished, training costs are estimated using rating and length of service criteria. These costs are then allocated forward in time on the basis of the number of years the trained cohort is expected to serve in the Navy.

j. Downtime Costs

An individual filling a billet spends time during the course of a full billet-year in nonproductive activities, such as training. This situation implies that another individual possessing a comparable level of skill and experience must be available to fill the billet during nonproductive periods. Thus, an upward adjustment of the preliminary total cost must be made to reflect the additional amount of cost required to fill a billet for a full man-year. The BCM makes this adjustment by

multiplying the sum of the previous nine elements by an estimated proportion of time during a year individuals in a rating spend as prisoners, patients, students, or in a transient status.

B. DEVELOPMENT OF RATING-SPECIFIC COSTS

The content and computation of each BCM cost element were carefully reviewed to determine if the cost estimates could be appropriately included in the development of replacement costs. Since the constant cost by grade element did not contain cost data and the constant cost by year element contained only selected reenlistment bonus costs which are incurred only after the first-term of enlistment, these elements were removed from consideration in constructing replacement costs. The portion of the all Navy cost by year element containing E-7 clothing costs also was considered to be inappropriate for the estimation of first-term replacement costs and was not considered in the computations. Additionally, the BCM's conceptualization of school costs, retirement costs, and downtime costs required additional consideration.

The allocation scheme used to distribute training costs over the number of years a trained enlisted member is explected to serve in the Navy was incompatable with the definition of a first-term replacement cost as the total cost to the U. S. Navy to replace an individual in a particular rating who attrites during a specified year of service prior to the completion of his or her first-term of enlistment. If the BCM's allocation of school costs to length of service cells was used in computing replacement cost estimations, the portion of the replacement costs which could be attributed to school costs would be seriously understated. For example, if an individual attrited at the end of his

or her first year of service, under the BCM's allocation scheme the training costs associated with the first year of service would only represent a fraction of the true costs of training which were incurred during the first year of service. The training expenditures required to replace such an individual would not be the fraction of the cost allocated to the first year of service, but rather would be the entire cost of training incurred in the first year of service. Thus, for the purpose of estimating replacement costs, rating-specific school costs were applied to the year of their occurrence.

The conceptualization of retirement as an accrued liability presented an even greater problem. Although the retirement cost element is appropriately included in the BCM, it was determined to have little relevance in relationship to first-term replacement costs. The concept of replacement cost as it relates to attrition implies that if an individual attrites prior to the completion of his or her initial enlistment, a certain amount of money must be invested to bring another individual up to the point where the first Navy member was lost through attrition. If the individual had not attrited, the additional cost would not have been incurred. In this context, retirement costs should not be included in computations of replacement costs, since no additional retirement cost is incurred by the Navy due to attrition among its members. In view of the foregoing, the cost element containing retirement costs was deleted from replacement cost computations.

The inclusion of downtime costs in replacement cost computations was also subject to question due primarily to the manner in which the BCM conceptualized such costs. Downtime costs represent the additional cost

incurred in filling a billet for a full man-year and are computed as a function of the amount of time an individual filling a billet or destined to fill a billet spends in nonproductive activities outside of the billet. Since the interest here is in replacement costs and not billet costs, downtime costs were deleted from replacement cost computations.

1. Replacement Cost Methodology

As a result of the review of each cost element, six basic cost elements were selected for use in estimating rating-specific, first-term replacement costs. Table 7 provides a listing of the cost elements utilized. Element costs were obtained from a March 1981 computer run of the Navy Enlisted Billet Cost Model. Rating-specific costs computed by length of service were used exclusively in the development of replacement costs.

Since the design of the BCM specifically guards against the double counting of costs, simple summations were applied in developing replacement costs. As with the estimation of survival functions, the typical first-term enlistee is considered to be serving in the Navy on an initial four-year enlistment obligation. If such an assumption is made, then $ERC^j_{n,i}$ can be interpreted as the magnitude of the n^{th} replacement cost element in the i^{th} year of service for the j^{th} Navy rating. It follows that

$$RC^j_i = \sum_{n=1}^{6} ERC^j_{n,i} \quad ; \quad \begin{array}{l} n = 1,2,3,\ldots,6 \\ i = 1,2,3,4 \\ j = \mathrm{ABE,ABF,ABH,\ldots,YN} \end{array}$$

where, RC^j_i is the replacement cost for the j^{th} Navy rating during the i^{th} year of service. It then follows that

TABLE 7

Navy Enlisted Billet Cost Model Elements
Utilized in Estimating Replacement Costs

Cost Element	Cost Element Components
Base Pay	Base Pay
Hazard Pay	Flight Crew Pay Submarine Crew Pay
FICA	Employer Social Security Taxes
A 1 Navy Cost by Grade	Sea and Foreign Duty Pay Family Separation Allowance Overseas Station Allowance Quarters Allowance in Cash Quarters Allowance in Kind Unemployment Insurance Commissary Medical/CHAMPUS PCS
All Navy Cost by Year	Accession Clothing Recruitment Messing and Subsistence Command and Administration Dependent School Death Gratuity Prisoner Apprehension Disability
School Costs	School Costs

$$CRC_k^j = \sum_{i=1}^{k} RC_i^j \qquad ; \quad \begin{array}{l} i = 1, 2, 3, 4 \\ k \geq i \\ j = \text{ABE, ABF, ABH, . . . , YN} \end{array}$$

where, CRC_k^j can be interpreted as the cumulative replacement cost for a Navy member in the j^{th} rating attriting in the k^{th} year of service.

2. Results

Table 8 presents the estimated cumulative replacement costs for the 85 ratings utilized in the study. Using a year three criterion, the five ratings having the highest replacement costs were found to be dental technician ($79,541), fire control technician (ballistic missile fire control) ($63,181), missile technician ($57,519), sonar technician ($54,377), and aviation fire control technician ($54,212). The ratings exhibiting the lowest replacement costs were molder ($37,685), utilities-man ($37,769), equipment operator ($37,818), aviation boatswain's mate (fuels) ($37,841), and builder ($37,885).

Based on the information contained in Table 6, four of the five ratings having the highest replacement costs are categorized as highly technical, while only one rating is categorized as technical. Among the five ratings having the lowest replacement costs, one is categorized as semi-technical and four as technical. Since the school cost element is the cost category which is the most discriminating among ratings, the ratings with high replacement costs appear to be generally consistent with the categorization of ratings by technical skill requirements.

Even more interesting is the appearance of three construction ratings among the five lowest replacement cost ratings. One possible explanation for such a high concentration is the Navy's policy of lateral

TABLE 8

Replacement Costs for U. S. Navy Ratings

Rating	Cumulative Replacement Costs by Year of Service			
	1	2	3	4
ABE	15,060	27,590	41,395	55,766
ABF	12,186	24,435	37,863	52,204
ABH	14,186	26,599	39,841	54,021
AC	14,507	27,133	41,520	56,793
AD	15,997	28,630	42,473	56,890
AE	16,074	28,887	42,707	57,303
AG	15,390	28,012	41,519	56,726
AK	14,522	27,054	40,433	54,665
AME	16,986	29,428	43,029	52,232
AMH	15,760	28,241	41,572	55,817
AMS	15,510	27,984	41,443	55,716
AO	15,259	27,677	41,356	55,713
AQ	22,586	39,179	54,212	68,955
ASE	15,529	28,137	41,880	56,800
ASH	14,696	27,307	40,809	55,124
ASM	15,575	28,269	42,215	57,161
AT	18,052	32,645	47,279	62,433

TABLE 8 (Cont'd)

Replacement Costs for U. S. Navy Ratings

	Cumulative Replacement Costs by Year of Service			
Rating	1	2	3	4
AW	16,308	29,527	44,025	59,701
AX	20,231	35,523	49,918	65,546
AZ	13,874	26,219	39,666	53,876
BM	13,173	25,502	38,502	52,726
BT	13,251	25,488	38,768	52,874
BU	12,200	24,420	37,885	53,091
CE	12,224	24,550	38,107	53,092
CM	12,341	24,549	38,036	52,926
CTA	14,355	26,706	40,247	55,141
CTI	13,160	25,533	38,984	53,201
CTM	18,578	35,502	50,040	66,429
CTO	14,398	26,820	40,397	54,864
CTR	14,946	27,246	40,738	54,857
CTT	15,786	28,177	41,809	56,715
DK	13,290	25,618	39,182	53,360
DM	14,249	26,660	40,001	54,936
DP	13,518	25,869	39,417	54,016
DS	13,601	26,259	40,626	55,901

TABLE 8 (Cont'd)

Replacement Costs for U. S. Navy Ratings

Ratings	Cumulative Replacement Costs by Year of Service			
	1	2	3	4
DT	35,777	62,148	79,541	97,773
EA	12,395	25,162	40,431	55,168
EM	14,882	31,700	45,598	60,525
EN	12,445	24,950	38,536	52,811
EO	12,230	24,453	37,818	52,417
ET	18,421	37,934	53,719	69,597
EW	18,468	38,565	52,743	68,154
FTB	29,432	46,329	63,181	81,574
FTG	16,595	33,034	47,063	62,116
FTM	13,739	28,165	42,160	57,375
GMG	13,254	25,664	38,948	53,639
GMM	15,905	28,501	41,885	57,039
GMT	16,585	29,429	43,171	57,894
GSE	14,557	28,630	43,593	58,808
GSM	14,909	28,116	42,592	58,649
HM	12,620	25,119	38,731	52,902
HT	13,419	25,802	39,411	54,298
IC	13,500	28,298	42,654	58,334

TABLE 8 (Cont'd)

Replacement Costs for U. S. Navy Ratings

	Cumulative Replacement Costs by Year of Service			
Ratings	1	2	3	4
IM	14,587	27,001	40,345	54,927
IS	14,127	26,781	40,406	56,238
JO	13,775	26,314	40,052	55, 168
LI	13,681	26,040	39,234	53,453
ML	12,313	24,520	37,685	52,044
MM	16,438	32,527	46,336	61,956
MN	13,849	26,620	40,153	56,296
MR	12,351	24,604	37,927	52,698
MS	14,495	26,839	40,119	54,420
MT	23,605	41,206	57,519	75,412
MU	13,134	25,369	38,957	53,120
OM	13,983	27,268	43,685	57,762
OS	14,427	26,865	40,187	54,643
OT	14,228	26,953	40,757	54,946
PC	12,294	25,245	38,628	52,894
PH	15,022	27,520	41,167	56,520
PM	12,613	24,821	38,682	52,743
PN	13,922	26,431	40,012	54,982

TABLE 8 (Cont'd)

Replacement Costs for U. S. Navy Ratings

	Cumulative Replacement Costs by Year of Service			
Ratings	1	2	3	4
PR	17,028	29,605	43,137	57,355
QM	13,519	25,847	39,336	54,185
RM	14,992	27,790	41,440	55,850
RP	14,428	27,010	40,729	54,837
SH	13,252	25,556	38,715	52,896
SK	13,254	25,566	38,946	53,098
SM	13,475	25,791	39,026	53,214
STG	16,354	29,970	48,590	65,934
STS	17,930	34,315	54,377	74,407
SW	12,306	24,623	38,132	53,371
TD	14,633	27,277	40,706	54,935
TM	14,689	27,327	41,598	56,804
UT	12,267	24,575	37,769	52,223
YN	13,184	25,507	38,924	53,118

entry into these ratings and the practice of bringing naval reservists, who have already been trained, on active duty in these ratings. Both practices would result in lower training costs.

V. DEMAND

The purpose of this chapter is to develop measures of size, shortfall or excess of requirements, and priority or relative importance for each of the 85 ratings included in the construction of a first-term attrition severity index. These three factors provide measures of the Navy's demand for individuals in specific ratings.

A. SIZE

First-term rating-specific measures of size are presented in Table 9. These measures were developed from rating inventory data contained in Fourth Quarter FY-80 Navy Military Personnel Statistics, a report provided quarterly by the Naval Military Personnel Command. Since the data of interest contained in the report are presented by paygrade rather than by length of service, identification of the paygrades which contain four-year first-term enlistees was necessary. Using rating-specific mean times to advancement, it was determined that the typical initial four-year enlistee entering the Navy in paygrade E1 advanced to paygrade E4 prior to the expiration of his or her first-term obligation. Thus, the rating-specific inventories for paygrades E1 through E4 were summed to derive estimations of first-term size for the 85 ratings utilized in the study.

B. SHORTAGE OR EXCESS OF REQUIREMENTS

The shortage or excess of enlisted personnel can be determined by comparing rating inventories with rating manpower requirements.

TABLE 9

Size and Shortage or Excess of Requirements for U. S. Navy Ratings

Rating	Size	Shortage or Excess[a]	Rating	Size	Shortage or Excess[a]
ABE	1,252	.16	AX	734	.08
ABF	1,126	.05	AZ	1,538	.13
ABH	1,933	.03	BM	3,544	.17
AC	979	.01	BT	7,741	.08
AD	6,613	.00	BU	1,368	.15
AE	3,264	.15	CE	520	.13
AG	911	.03	CM	841	-.02
AK	2,982	.13	CTA	362	.07
AME	1,487	.07	CTI	204	.20
AMH	2,913	.05	CTM	592	.06
AMS	4,254	.08	CTO	720	.16
AO	3,096	.17	CTR	840	.03
AQ	892	.28	CIT	609	.18
ASE	342	.16	DK	853	.13
ASH	392	.02	DM	170	-.19
ASM	583	-.04	DP	1,757	.11
AT	3,612	.14	DS	831	.02
AW	1,208	.11	DT	2,226	.19

TABLE 9 (Cont'd)

Size and Shortage or Excess of Requirements for U. S. Navy Ratings

Rating	Size	Shortage or Excess[a]	Rating	Size	Shortage or Excess[a]
EA	153	.09	IS	420	.09
EM	5,839	.06	JO	339	.11
EN	4,880	.03	LI	202	.05
EO	1,099	.09	ML	115	-.03
ET	6,749	.05	MM	12,296	.08
EW	762	.24	MN	584	.09
FTB	382	-.01	MR	1,235	.11
FTG	1,229	.12	MS	890	-.08
FTM	1,556	.14	MU	254	.42
GMG	1,714	.12	OM	118	.18
GMM	708	.15	OS	4,116	.38
GMT	944	.11	OT	624	.16
GSE	163	-.31	PC	651	.16
GSM	346	.04	PH	1,114	-.13
HM	12,386	.18	PM	61	.00
HT	6,410	.07	PN	2,622	.08
IC	2,549	.15	PR	977	.12
IM	174	.28	QM	2,004	.12

TABLE 9 (Cont'd)

Size and Shortage or Excess of Requirements
for U. S. Navy Ratings

Rating	Size	Shortage or Excess[a]	Rating	Size	Shortage or Excess[a]
RM	7,449	.16	STS	1,380	-.06
RP	147	.09	SW	636	.06
SH	2,424	.17	TD	725	.12
SK	3,950	.06	TM	1,596	.16
SM	1,680	.23	UT	670	.11
STG	2,343	.02			

[a] Shortage or Excess = (Requirements - Inventory)/Requirements.

If the requirements outnumber the inventory, than a shortage exists. Conversely, if the inventory exceeds the requirements, an excess of manpower exists. The magnitude of the shortage or excess can be expressed as a proportion of requirements, where a positive percentage indicates a shortage and a negative percentage indicates an excess.

Using the data provided in Fourth Quarter FY-80 Navy Military Personnel Statistics, rating-specific measures of shortages and excesses were estimated. The results are presented as proportions in Table 9. The measures presented were computed from inventory and requirement data for paygrades E3 through E9, rather than solely for those paygrades which typically contain first-term personnel. Since requirements for E1 and E2 personnel are not formally established within the Navy's billet structure, these paygrades could not be used in the computations. Paygrades E3 through E9 were chosen to capture the full impact of attrition on specific ratings, recognizing the Navy's bottom-up policy of developing raw personnel inputs, through training and experience, into skilled manpower. The loss of first-term personnel through attrition not only affects the Navy's ability to meet requirements typically filled by first-term personnel, but also affects the Navy's ability to maintain an adequate number of personnel to develop and advance into the more skilled positions in the higher paygrades. Thus, if severe shortages already exist in the higher paygrades in a particular rating, the effect of first-term attrition is more severe than it would be if such shortages did not exist.

C. PRIORITY

Any measure of rating priority or the importance of a particular rating to the Navy in carrying out its national defense role in times

of international conflict must be subjective in nature, requiring judgments on the part of a qualified or knowledgable group of raters. Since subjective judgments are necessary, measures of this kind will vary to some extent among different groups or raters.

One method of obtaining a ratio scale for the relative importance to the Navy of the various Navy ratings would be through a Delphi method of obtaining a consensus of opinion of a group of experts (Pill, 1971). An iterative procedure could be used by which a group of experienced senior officers could provide several rounds of responses to questions on the relative importance of Navy ratings. This method contains features of mutual anonymity, controlled feedback, and statistical group response.

On round one, each expert would be asked to attach an importance value of zero to 100 to each of the 85 ratings. The scale would be anchored at 100 for the machinist's mate rating and zero for the musician rating. Disagreement with these extremes would necessitate a separate iterative process.

The responses from this iteration would be put in the form of a matrix, X, where $X_{i,j}$ is the j^{th} expert's scale value for the i^{th} rating. If there were no agreement between the expert's assessment of scale value for a rating, then the ten scale values for that rating would be coming from a uniform distribution with a mean of 50 and variance $(100-0)^2/12 = 83.3$. The sample variance for the i^{th} rating, S_i^2, would be calculated as

$$S_i^2 = \sum_{j=1}^{10} (X_{i,j} - \bar{X}_i)^2 \,/\, (10-1)$$

where $\bar{X}_i$ is the mean scale value for the i^{th} rating.

As agreement on the experts' scale values for rating i increases, the test statistic A_i will approach zero, where

$$A_i = (10-1)\ S_i^2\ /\ 83.3$$

When there is no agreement among the experts, the test statistic will give a chi-square distribution with nine degrees of freedom.

A 10% critical value for $\chi^2(9)$ variate is 4.168. By calculating A_i for each rating and using the interval $[0, 4.2]$ as the agreement interval, we can assess a rating to either have an agreed scale value of $\overline{X}_i$, or to be in disagreement.

The second iteration involves sending each judge the scale value $\overline{X}_i$ for each rating in agreement and requesting them to scale the remaining ratings not yet in agreement. Upon receipt of their new scale values, we apply the criterion of agreement using newly calculated test statistics for each previously unagreed upon rating. If any ratings remain unagreed upon, then the second iteration is repeated.

At each iteration, the coefficient of concordance as discussed by Kendall (1970) would be calculated. The stopping rule would be to stop if either a) the coefficient of concordance exceeds .95, b) all ratings meet the agreement criteria, or c) the fourth iteration is reached. Any ratings not meeting the agreement criteria at this point would be assigned their respective mean scale value.

Time did not permit the completion of an iterative process for inclusion in this thesis. Instead, a prototype, personally derived measure was utilized for capturing the relative importance of Navy ratings. Since the thrust of this thesis is the development of a

single attrition severity index incorporating information on factors of attrition, the prototype measure of relative importance given in Table 10 will be utilized in the derivation of an attrition severity index.

The measures provided have been transformed into a distribution which has a mean of 50 and a standard deviation of 10. When placed in such a distribution, a numerical value of 80 would indicate extremely high priority or importance, while 20 would indicate very low priority. For example, the machinist's mate rating has a very high priority value of 69. At the other end of the scale, the musician rating has a very low priority value of 29.

D. RESULTS

The results provided in this chapter again indicate the variance in rating-specific measures which affect first-term attrition severity. All three demand factors considered varied widely among ratings. In the area of rating size, the machinist's mate (12,296), hospital corpsman (12,386), mess management specialist (7,905), boiler technician (7,741), and radioman (7,449) ratings provided the greatest demand for first-term personnel, while the patternmaker (61), molder (115), [illegible]icalman (118), religious program specialist (147), and engineering aid (153) ratings provided the lowest demand. When the extent to which requirements matched rating-specific inventories was examined, the five ratings exhibiting the greatest shortfall in personnel were the musician (.42), operations specialist (.38), instrumentman (.28), aviation fire control technician (.28), and electronics warfare technician (.24) ratings. Conversely, the ratings which exhibited the

TABLE 10

Priority of U. S. Navy Ratings

Rating	Priority	Rating	Priority
ABE	47	AZ	37
ABF	47	BM	45
ABH	47	BT	65
AC	45	BU	44
AD	51	CE	42
AE	54	CM	35
AG	41	CTA	49
AK	38	CTI	57
AME	52	CTM	50
AMH	52	CTO	54
AMS	52	CTR	60
AO	49	CTT	56
AQ	57	DK	49
ASE	41	DM	32
ASH	41	DP	42
ASM	41	DS	53
AT	59	DT	47
AW	59	EA	38
AX	60	EM	57

TABLE 10 (Cont'd)

Priority of U. S. Navy Ratings

Rating	Priority	Rating	Priority
EN	49	MM	69
EO	45	MM	69
ET	53	MN	50
EW	59	MR	45
FTB	66	MS	49
FTG	66	MT	66
FTM	66	MU	29
GMG	66	OM	34
GMM	66	OS	65
GMT	58	OT	56
GSE	59	PC	45
GSM	59	PH	43
HM	59	PM	35
HT	55	PN	49
IC	59	PR	53
IM	36	QM	54
IS	45	RM	62
JO	32	RP	31
LI	32	SH	56
ML	35	SK	51

TABLE 10 (Cont'd)

Priority of U. S. Navy Ratings

Rating	Priority	Rating	Priority
SM	69	TD	50
STG	53	TM	59
STS	62	UT	42
SW	39	YN	49

largest excess of manpower were the gas turbine system technician (electrical) (-.31), illustrator draftsman (-.19), photographer's mate (-.13), missile technician (-.08), and sonar technician (submarine) (-.06) ratings. Additionally, the subjective measures used to determine rating importance or priority provided a similar profile of widely varying values, with the machinist's mate (69), signalman (69), fire control technician (ballistic missile fire control) (66), gunner's mate (guns) (66), and missile technician (66) ratings among those groups receiving the highest priorities, and the musician (29), religious program specialist (31), patternmaker (32), journalist (32), and lithographer (32) ratings among those receiving the lowest priorities.

When considering all five factors (survival, replacement cost, size, shortage or excess of requirements, and priority) for inclusion in the construction of the first-term attrition severity index, the preliminary results indicate a diverse impact of the factors on individual ratings. For example, the missile technician rating was categorized at the extreme ends of the scale for four out of the five factors developed. However, the directional impact of these four factors on attrition severity differed markedly. The high probability of survival among missile technicians and the excess of manpower resources in the rating would indicate low first-term attrition severity, while the rating's high priority and high replacement cost would indicate high attrition severity. The diversity of the effect of each of the factors on specific ratings indicates the need to apply a muliattribute model to the data which will collapse the five factors to a single value before a determination of rating-specific attrition severity can be easily made.

VI. FIRST-TERM ATTRITION SEVERITY INDEX

The purpose of this chapter is to develop a multiattribute model which will utilize the factors developed for survival, replacement cost, size, shortage or excess of requirements, and priority, to produce a first-term attrition severity index for the 85 Navy ratings considered in the study.

A. FACTOR SELECTION CRITERIA

Although the factors of size, shortage or excess of requirements, and priority were developed as single rating-specific measures, survival and replacement cost were developed for the four-year period which typified the length of the initial service obligation for the average Navy enlistee. Consequently, selection of a single rating-specific measure to be used in the first-term attrition severity index for each of these two factors was necessary.

1. Survival

Since the rating-specific survival estimates developed contain an acknowledged bias due to the fact that such measures only represent survival after individuals reach designated rating status, the data were closely scrutinized to determine the best single measure of rating-specific survival. Table 11 presents the results of correlations calculated among yearly survival rates and selected cumulative survival functions.

TABLE 11

Pearson Correlation Matrix for Yearly Survival Rates and Cumulative Survival Functions

Variable	Year 1	Year 2	Year 3	Year 4	Year 23[d]	Year 123[e]
Year 1	--	.1983[c]	.8376[a]	.2169[c]	.8901[a]	.8901[a]
Year 2	.1983[c]	--	.2976[b]	.2778[b]	.6226[a]	.5034[a]
Year 3	.8376[a]	.2976[b]	--	.2204[c]	.8082[a]	.9499[a]
Year 4	.2169[c]	.2778[b]	.2204[c]	--	.3043[b]	.2895[b]
Year 23[d]	.8901[a]	.6226[a]	.8082[a]	.3043[b]	--	.9473[a]
Year 123[e]	.8922[a]	.5034[a]	.9499[a]	.2895[b]	.9473[a]	--

[a] Significant at the .001 level.

[b] Significant at the .01 level.

[c] Significant at the .05 level.

[d] The product of the survival rates for years 2 and 3.

[e] The product of the survival rates for years 1, 2, and 3.

The yearly survival rates represent survival in specific years, while the cumulative survival functions are the products of two or more yearly survival rates. As expected, due to the infusion of reenlistment behavior into the estimates, survival in year four provided only moderately positive correlation coefficients. When considering estimates for those years in which survival was based on wastage attributed solely to attrition, the year two estimate appears to be the least correlated with other years, and may be the year most affected by the bias in the data. By far, the cumulative survival functions provided the highest correlations, with the third year estimate providing the best results. Thus, the third year rating-specific cumulative survival functions, which are the products of the year one, two, and three survival rates, were chosen for use in determining first-term attrition severity.

2. Replacement Cost

Table 12 presents the correlations among yearly replacement costs and cumulative replacement costs. The results reveal very high positive correlations among the cost estimates considered. Since the third year cumulative replacement costs provided correlations of .92 and above, and the measure corresponds to the third year cumulative survival functions chosen for use in the development of the first-term attrition severity index, the third year cumulative replacement costs were selected for use.

B. FACTOR DATA

Table 13 presents the rating-specific measures developed in previous chapters for each of the five factors considered appropriate

TABLE 12

Pearson Correlation Matrix for Yearly Replacement Costs and Cumulative Replacement Costs

Variable	Year 1	Year 2	Year 3	Year 4	Year 12[a]	Year 123[b]	Year 1234[c]
Year 1	--	.8611	.9634	.8274	.9787	.9793	.9544
Year 2	.8611	--	.8938	.9529	.9472	.9298	.9510
Year 3	.9634	.8938	--	.9171	.9688	.9909	.9872
Year 4	.8274	.9529	.9171	--	.9069	.9188	.9553
Year 12[a]	.9787	.9472	.9688	.9069	--	.9933	.9862
Year 123[b]	.9793	.9298	.9909	.9188	.9933	--	.9944
Year 1234[c]	.9544	.9510	.9872	.9553	.9862	.9944	--

Note. All values significant at the .001 level

[a] The sum of the replacement costs for years 1 and 2.

[b] The sum of the replacement costs for years 1, 2, and 3.

[c] The sum of the replacement costs for years 1, 2, 3, and 4.

TABLE 13

Summary of First-Term Attrition Severity Factors
for U. S. Navy Ratings

Rating	Survival	Replacement Cost	Size	Shortage/Excess of Requirements	Priority
ABE	.8488	41,395	1,252	.16	47
ABF	.8421	37,863	1,126	.05	47
ABH	.8150	39,841	1,933	.03	47
AC	.8953	41,520	979	.01	45
AD	.8741	42,473	6,613	.00	51
AE	.9194	42,707	3,264	.15	54
AG	.8426	41,519	911	.03	41
AK	.7583	40,433	2,098	.13	38
AME	.8745	43,029	1,487	.07	52
AMH	.8517	41,572	2,913	.05	52
AMS	.8814	41,443	4,254	.08	52
AO	.8289	41,356	3,096	.17	49
AQ	.8444	54,212	892	.28	57
ASE	.8510	41,880	342	.16	41
ASH	.7858	40,809	392	.02	41
ASM	.7922	42,215	583	-.04	41
AT	.8770	47,279	3,612	.14	59
AW	.8674	44,025	1,208	.11	43
AX	.9193	49,918	734	.08	60

TABLE 13 (Cont'd)

Summary of First-Term Attrition Severity Factors
for U. S. Navy Ratings

Rating	Survival	Replacement Cost	Size	Shortage/Excess of Requirements	Priority
AZ	.7472	39,666	1,538	.13	37
BM	.8846	38,502	3,544	.17	45
BT	.7563	38,768	7,741	.08	65
BU	.8713	37,885	1,368	.15	44
CE	.8560	38,107	520	.13	42
CM	.8580	38,036	841	-.02	35
CTA	.7529	40,247	362	.07	49
CTI	.9455	38,984	204	.20	57
CTM	.9102	50,040	592	.06	50
CTO	.8380	40,397	720	.16	54
CTR	.7910	40,738	840	.03	60
CTT	.8637	41,809	609	.18	56
DK	.8142	39,182	853	.13	49
DM	.6028	40,001	170	-.19	32
DP	.8380	39,417	1,757	.11	42
DS	.9216	40,626	831	.02	53
DT	.8003	79,541	2,226	.19	47
EA	.8053	40,431	153	.09	38
EM	.8315	45,598	5,839	.06	57

TABLE 13 (Cont'd)

Summary of First-Term Attrition Severity Factors
for U. S. Navy Ratings

Rating	Survival	Replacement Cost	Size	Shortage/Excess of Requirements	Priority
EN	.8015	38,536	4,880	.03	49
EO	.8059	37,818	1,099	.09	45
ET	.8366	53,719	6,749	.05	53
EW	.9101	52,743	762	.24	59
FTB	.8524	63,181	382	-.01	66
FTG	.8687	47,063	1,229	.12	66
FTM	.8228	42,160	1,556	.14	66
GMG	.7947	38,948	1,714	.12	66
GMM	.8267	41,885	708	.15	66
GMT	.8643	43,171	944	.11	58
GSE	1.000	43,593	163	-.31	59
GSM	.9054	42,592	346	.04	59
HM	.8130	38,731	12,296	.18	59
HT	.8111	39,411	6,410	.07	55
IC	.8438	42,654	2,549	.15	59
IM	.8286	40,345	174	.28	36
IS	.8505	40,406	420	.09	45
JO	.7614	40,052	339	.11	32
LI	.8629	39,234	202	.05	32

TABLE 13 (Cont'd)

Summary of First-Term Attrition Severity Factors
for U. S. Navy Ratings

Rating	Survival	Replacement Cost	Size	Shortage/Excess of Requirements	Priority
ML	.7471	37,685	115	-.03	35
MM	.7783	46,336	12,296	.08	69
MN	.8302	40,153	584	.09	50
MR	.8739	37,927	1,235	.11	45
MS	.6937	40,119	7,905	.16	49
MT	.9446	57,519	890	-.08	66
MU	.9098	38,957	254	.42	29
OM	.6667	43,685	118	.18	34
OS	.8044	40,187	4,116	.38	65
OT	.7119	40,757	624	.16	56
PC	.7353	38,628	651	.16	45
PH	.8831	41,167	1,114	-.13	43
PM	.9231	38,682	61	.00	35
PN	.7348	40,012	2,662	.08	49
PR	.7914	43,137	977	.12	53
QM	.8049	39,336	2,004	.12	54
RM	.7800	41,440	7,449	.16	62
RP	.7555	40,729	147	.09	31
SH	.6963	38,715	2,424	.17	56

TABLE 13 (Cont'd)

Summary of First-Term Attrition Severity Factors
for U. S. Navy Ratings

Rating	Survival	Replacement Cost	Size	Shortage/Excess of Requirements	Priority
SK	.8113	38,946	3,950	.06	51
SM	.7198	39,026	1,680	.23	69
STG	.8230	48,590	2,343	.02	53
STS	.8214	54,377	1,380	-.06	62
SW	.8234	38,132	636	.06	39
TD	.7701	40,706	725	.12	50
TM	.7719	41,598	1,596	.16	59
UT	.8172	37,769	670	.11	42
YN	.7851	38,924	4,240	.18	49

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A FIRST-TERM ATTRITION SEVERITY INDEX FOR U. S. NAVY RATINGS.(U)

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for use in determining first-term attrition severity. Such a presentation provides little insight into the impact of attrition on individual ratings, since the five attributes are measured in different units and are members of different distributions. In order to gain a better insight into the data, rating specific measures within each factor were transformed into standardized distributions having a mean of 50 and a standard deviation of 10. The transformation of the values provides a scale which runs approximately from 20 to 80 with very few values falling more than three standard deviations above or below the mean. When placed in such a distribution, a factor value of 20 or less would indicate a very low impact on attrition severity for the specific factor considered, and a value of 80 or more would indicate a very high impact. However, prior to the standardization of the factors, it was necessary to examine the directional impact of the factors on first-term attrition to ensure that each factor was affecting attrition in the same manner as all others. For the replacement cost, size, shortage or excess of requirements, and priority factors, as the rating-specific measures increased in value, the severity of attrition also increased. However, the impact of the survival factor was in the opposite direction. As survival increased, the severity of attrition decreased. In order to correct the directional problem existing in the data, rating-specific survival measures were recalculated as cumulative wastage or attrition rates by subtracting one from the cumulative survival rate prior to standardization of the factor. The standardized rating-specific factors are presented in Table 14.

TABLE 14

Standardized First-Term Attrition Severity Factors
for U. S. Navy Ratings
(mean = 50, standard deviation = 10)

Rating	Survival	Replacement Cost	Size	Shortage/Excess of Requirements	Priority
ABE	46	48	47	56	47
ABF	47	43	46	45	47
ABH	52	46	50	44	47
AC	39	48	46	42	45
AD	43	50	68	41	51
AE	36	50	55	55	54
AG	47	48	45	44	41
AK	60	47	50	53	38
AME	43	51	48	47	52
AMH	46	49	53	45	52
AMS	42	48	59	48	52
AO	49	48	54	57	49
AQ	47	69	45	68	57
ASE	46	49	43	56	41
ASH	56	47	43	43	41
ASM	55	50	44	37	41
AT	42	58	56	54	59
AW	44	52	47	51	43

TABLE 14 (Cont'd)

Standardized First-Term Attrition Severity Factors
for U. S. Navy Ratings
(mean = 50, standard deviation = 10)

Rating	Survival	Replacement Cost	Size	Shortage/Excess of Requirements	Priority
AX	36	62	45	48	60
AZ	62	45	48	53	37
BM	41	44	56	57	45
BT	60	44	73	48	65
BU	43	43	47	55	44
CE	45	43	44	53	42
CM	45	43	45	39	35
CTA	61	46	43	47	49
CTI	32	44	43	60	57
CTM	37	62	44	46	50
CTO	48	47	45	56	54
CTR	55	47	45	44	60
CTT	44	49	44	58	56
DK	52	45	45	53	49
DM	83	46	42	22	32
DP	48	45	49	51	42
DS	35	47	45	43	53
DT	54	109	51	59	47

TABLE 14 (Cont'd)

Standardized First-Term Attrition Severity Factors
for U. S. Navy Ratings
(mean = 50, standard deviation = 10)

Rating	Survival	Replacement Cost	Size	Shortage/Excess of Requirements	Priority
EA	53	47	42	49	38
EM	49	55	65	46	57
EN	54	44	61	44	49
EO	53	43	46	49	45
ET	48	68	69	45	53
EW	37	66	45	64	59
FTB	46	83	43	40	66
FTG	43	57	47	52	66
FTM	50	49	48	54	66
GMG	55	44	49	52	66
GMM	50	49	45	55	66
GMT	44	51	46	51	58
GSE	24	52	42	11	59
GSM	38	50	43	45	59
HM	52	44	91	58	59
HT	52	45	67	47	55
IC	47	50	52	55	59
IM	49	47	42	68	36

TABLE 14 (Cont'd)

Standardized First-Term Attrition Severity Factors
for U. S. Navy Ratings
(mean = 50, standard deviation = 10)

Rating	Survival	Replacement Cost	Size	Shortage/Excess of Requirements	Priority
IS	46	47	43	49	45
JO	60	46	43	51	32
LI	44	45	43	45	32
ML	62	42	42	38	35
MM	57	56	91	48	69
MN	49	46	44	49	50
MR	43	43	47	51	45
MS	70	46	73	56	49
MT	32	74	45	33	66
MU	37	44	43	81	29
OM	74	52	42	58	34
OS	53	46	58	77	65
OT	67	47	44	56	56
PC	63	44	44	56	45
PH	41	48	46	28	43
PM	35	44	42	41	35
PN	64	46	52	48	49
PR	55	51	46	57	53

TABLE 14 (Cont'd)

Standardized First-Term Attrition Severity Factors
for U. S. Navy Ratings
(mean = 50, standard deviation = 10)

Rating	Survival	Replacement Cost	Size	Shortage/Excess of Requirements	Priority
QM	53	45	50	52	54
RM	57	48	72	56	62
RP	60	47	42	49	31
SH	69	44	51	57	56
SK	52	44	58	46	51
SM	66	44	49	63	69
STG	50	60	51	43	53
STS	51	69	47	35	62
SW	50	43	44	46	39
TD	58	47	45	52	50
TM	58	48	48	56	59
UT	51	42	44	51	42
YN	56	44	59	58	49

An even better presentation of the data can be made by ranking the standardized factors across the 85 ratings used in the study. The results of the ranking procedure are presented in Table 15. For any factor under consideration, a ranking of 1 indicates the smallest rating-specific value for that factor, while a ranking of 85 indicates the largest rating-specific value. When ranked in such a manner, a ranking of 1 indicates a low attrition impact, while a ranking of 85 indicates a high severity impact.

The data presented in Tables 14 and 15, would tend to validate the belief that the five factors developed vary widely across Navy ratings and the factors vary in their impact on specific ratings. The standardized data clearly provide evidence that for any factor considered, the factor measures vary to a large degree across ratings. Likewise, the ranked data provides a unique presentation of the data that would indicate a varying impact of the five factors on specific ratings. For example, the aviation antisubmarine warfare technician rating was ranked very low for survival (7), ranked in the moderate range for size (31) and shortage or excess of requirements (36), and ranked very high for replacement cost (77) and priority (73). Such a dispersion of rankings would provide preliminary evidence of a need to utilize a multiattribute model for determining rating-specific attrition severity.

When considering the correlation of factors presented in Table 16, a moderately positive correlation is seen to exist between size and priority (.37) and between cost and priority (.31). The correlations are extremely low between all other factors. Such results provide even stronger evidence that there is a need to combine the factors in order to determine rating-specific attrition severity.

TABLE 15

Ranking of First-Term Attrition Severity Factors
for U. S. Navy Ratings
(1 = lowest attrition impact; 85 = highest attrition impact)

Rating	Survival	Replacement Cost	Size	Shortage/Excess of Requirements	Priority
ABE	32	50	49	69	33
ABF	36	4	45	22	32
ABH	50	29	59	16	31
AC	12	55	42	12	30
AD	18	62	79	11	45
AE	6	65	69	62	56
AG	35	54	39	19	17
AK	72	41	61	55	12
AME	17	66	52	30	49
AMH	29	56	67	24	47
AMS	15	52	75	32	48
AO	42	49	68	72	37
AQ	33	81	38	82	61
ASE	30	58	13	70	15
ASH	65	47	17	15	18
ASM	62	61	20	6	16
AT	16	75	71	57	65
AW	22	71	46	43	22

TABLE 15 (Cont'd)

Ranking of First-Term Attrition Severity Factors
for U. S. Navy Ratings
(1 = lowest attrition impact; 85 = highest attrition impact)

Rating	Survival	Replacement Cost	Size	Shortage/Excess of Requirements	Priority
AX	7	77	31	36	73
AZ	76	28	53	53	11
BM	13	10	70	71	26
BT	73	16	82	33	77
BU	20	5	50	59	24
CE	27	8	19	56	19
CM	26	7	35	8	8
CTA	75	36	15	29	39
CTI	2	21	10	79	62
CTM	8	78	22	28	43
CTO	37	38	29	66	55
CTR	64	45	34	18	72
CTT	24	57	23	76	60
DK	51	23	36	54	40
DM	85	30	7	2	4
DP	38	27	58	47	21
DS	5	42	33	13	53
DT	60	85	62	78	34

TABLE 15 (Cont'd)

Ranking of First-Term Attrition Severity Factors
for U. S. Navy Ratings
(1 = lowest attrition impact; 85 = highest attrition impact)

Rating	Survival	Replacement Cost	Size	Shortage/Excess of Requirements	Priority
EA	56	40	5	40	13
EM	40	72	77	25	63
EN	59	11	76	17	41
EO	55	3	43	37	29
ET	39	80	80	23	51
EW	9	79	32	81	66
FTB	28	84	16	9	83
FTG	21	74	47	51	79
FTM	47	60	54	58	78
GMG	61	19	57	48	80
GMM	44	59	28	60	81
GMT	23	68	40	44	64
GSE	1	69	6	1	71
GSM	11	63	14	20	70
HM	52	15	85	74	67
HT	54	26	78	31	57
IC	34	64	65	61	68
IM	43	37	8	83	10

TABLE 15 (Cont'd)

Ranking of First-Term Attrition Severity Factors
for U. S. Navy Ratings
(1 = lowest attrition impact; 85 = highest attrition impact)

Rating	Survival	Replacement Cost	Size	Shortage/Excess of Requirements	Priority
IS	31	39	18	38	28
JO	71	32	12	42	3
LI	25	24	9	21	5
ML	77	1	2	7	9
MM	68	73	84	34	85
MN	68	73	84	34	85
MN	41	34	21	39	44
MR	19	6	48	45	27
MS	83	33	83	64	35
MT	3	83	37	4	82
MU	10	20	11	85	1
OM	84	70	3	77	6
OS	58	35	73	84	76
OT	81	46	24	68	59
PC	78	12	26	67	25
PH	14	48	44	3	23
PM	4	13	1	10	7
PN	79	31	66	35	38

TABLE 15 (Cont'd)

Ranking of First-Term Attrition Severity Factors
for U. S. Navy Ratings
(1 = lowest attrition impact; 85 = highest attrition impact)

Rating	Survival	Replacement Cost	Size	Shortage/Excess of Requirements	Priority
PR	63	67	41	52	50
QM	57	25	60	49	54
RM	67	51	81	65	74
RP	74	44	4	41	2
SH	82	14	64	73	58
SK	53	18	72	26	46
SM	80	22	56	80	84
STG	46	76	63	14	52
STS	48	82	51	5	75
SW	45	9	25	27	14
TD	70	43	30	50	42
TM	69	53	55	63	69
UT	49	2	27	46	20
YN	66	17	74	75	36

TABLE 16

Pearson Correlation Matrix for All First-Term Attrition Severity Index Factors

Variable	Survival	Cost	Size	Requirement	Priority
Survival	--	-.1881[c]	.1517	.1158	-.1597
Cost	-.1881[c]	--	.0067	-.0540	.3063[b]
Size	.1517	.0067	--	.1015	.3740[a]
Requirement	.1158	-.0540	.1015	--	.0700
Priority	-.1597	.3063[b]	.3740	.0700	--

[a] Significant at the .001 level.

[b] Significant at the .01 level.

[c] Significant at the .05 level.

C. DEVELOPMENT OF THE FIRST-TERM ATTRITION SEVERITY INDEX

When applying a multiattribute model to any set of data, a question invariably arises regarding the correct method to use in combining the different attributes or factors. Little definitive information currently is available which prescribes the use of specific methods. In the face of such uncertainty, experts have generally resorted to using two basic types of models, the additive and multiplicative models. Evidence is available which would seem to point to the comparability of the results derived from the two different models (Van Gigch, 1978). For the purposes of developing a first-term attrition severity index, the multiplicative form will be applied to the factor data which have been developed.

If we let

N_{ij} = the i^{th} factor or attribute value for the j^{th} rating for $i = 1,2,3,4,5$ and j = ABE,ABF,ABH,...,YN

and

x_i = the weighting for the i^{th} factor or attribute for $i = 1,2,3,4,5$

then a first-term attrition severity index (ASI) can be defined as

$$ASI_j = \frac{\prod_{i=1}^{5} N_{ij}^{x_i}}{\text{Maximum}\left[\prod_{i=1}^{5} N_{ij}^{x_i}\right]} \qquad (100)$$

The scaling effect of the model presented provides a first-term attrition severity index for Navy ratings that potentially ranges from 100 for the rating experiencing the most severe attrition to zero for the rating experiencing the least severe attrition.

D. RESULTS

Using the standardized factor values as input to the model and weighting the factors equally with a weighting of 1, rating specific first-term attrition severity index values were derived. Table 17 presents the correlations among the input factors and the resulting attrition severity index values. The results indicate a moderately high correlation between size and the attrition severity index, while indicating almost no correlation between cost and the index. At first glance, it would appear that the size factor is driving the index, while the cost factor is contributing very little. However, due to the positive correlation between size and priority, the size factor may not be acting independently, but rather in conjunction with the priority factor, partially capturing the effect of the priority variable. Likewise, the priority factor may be partially capturing the effect of the cost variable, driving the correlation between the attrition severity index and the cost factor downward. If these interpretations are accurate, than no single factor can be used to determine rating-specific first-term attrition severity.

Although equal explicit weights were used in calculating the primary index output, factor weights may be varied to provide an index which emphasizes the relative importance of individual factors. In order

TABLE 17

Pearson Correlation Matrix for All Factors and First-Term Attrition Severity Index (ASI)

Variable	Survival	Cost	Size	Requirement	Priority	ASI
Survival	--	-.1881[c]	.1517	.1158	-1597	.3926[a]
Cost	-.1881[c]	--	.0067	-.0540	.3063[b]	.1758
Size	.1517	.0067	--	.1015	.3740[a]	.7499[a]
Requirement	.1158	-.0540	.1015	--	.0700	.4677[a]
Priority	-.1597	.3063[b]	.3740	.0700	--	.6042[a]
ASI	.3926[a]	.1758	.7499[a]	.4677[a]	.6042	--

[a] Significant at the .001 level.

[b] Significant at the .01 level.

[c] Significant at the .05 level.

to determine the effect of weighting on the index, three separate attrition severity indexes were calculated using three different weights, and correlations were calculated among the results. Table 18 provides the results of the procedure when each factor was separately weighted by a power of two, while the weights of the other four factors were equally weighted with an exponent of one. The weighted attrition severity indexes were than correlated with the equally weighted index. Tables 19 and 20 present the results of similar procedures using weights of five and ten, respectively. The extremely high positive correlation between the index calculated using equal weights and the indexes derived when the individual factors were raised to the second power indicate that such a weighting would have little impact on index values. However, the decreasing positive correlations realized when the index is weighted by powers of five and ten, indicate that a weight of at least three or more must be applied to begin to make any one factor a substantially more significant determinant of first-term attrition severity.

Table 21 presents first-term attrition severity index values for the 85 ratings considered in the thesis and relative rankings based on the index values. The ranking in Table 21 is from least severe to most severe. In most cases, the results provided by the index correspond with anticipated outcomes. Groups which have long been considered critical to the Navy in terms of manpower, such as the boiler technician, machinist's mate, operations specialist, and fire control technician (ballistic missile fire control) ratings, were among those receiving the highest index values. Likewise, those ratings which have not been considered critical, such as the photographer's mate, lithographer, musician,

TABLE 18

Pearson Correlation Matrix for ASI's Weighted by Powers of Two and an Equally Weighted ASI

Variable	ASI (Survival^2)	ASI (Cost^2)	ASI (Size^2)	ASI (Requirement^2)	ASI (Priority^2)	ASI (Equal Weights)
ASI (Survival^2)	--	.8065	.9038	.9226	.9175	.9613
ASI (Cost^2)	.8065	--	.7690	.8348	.8225	.8838
ASI (Size^2)	.9038	.7690	--	.8650	.9226	.9382
ASI (Requirement^2)	.9226	.8348	.8650	--	.9235	.9612
ASI (Priority^2)	.9175	.8225	.9226	.9235	--	.9731
ASI (Equal Weights)	.9613	.8838	.9382	.9612	.9731	--

Note. All values significant at the .001 level.

TABLE 19

Pearson Correlation Matrix for ASI's Weighted by Powers of Five and an Equally Weighted ASI

Variable	ASI ($Survival^5$)	ASI ($Cost^5$)	ASI ($Size^5$)	ASI ($Requirement^5$)	ASI ($Priority^5$)	ASI (Equal Weights)
ASI ($Survival^5$)	--	.1780	.4667[a]	.4461[a]	.5260[a]	6976[a]
ASI ($Cost^5$)	.1780	--	.0840	.2731[b]	.1490	.4295[a]
ASI ($Size^5$)	.4667[a]	.0840	--	.2907[b]	.6810[a]	.6924[a]
ASI ($Requirement^5$)	.4461[a]	.2731[b]	.2907[b]	--	.5561[a]	.6756[a]
ASI ($Priority^5$)	.5260[a]	.1490	.6810[a]	.5561[a]	--	.8417[a]
ASI (Equal Weights)	.6976[a]	4295	.6924[a]	.6756[a]	.8417[a]	--

[a] Significant at the .001 level.

[b] Significant at the .01 level.

[c] Significant at the .05 level.

TABLE 20

Pearson Correlation Matrix for ASI's Weighted by Powers of Ten and an Equally Weighted ASI

Variable	ASI ($Survival^{10}$)	ASI ($Cost^{10}$)	ASI ($Size^{10}$)	ASI ($Requirement^{10}$)	ASI ($Priority^{10}$)	ASI (Equal Weights)
ASI ($Survival^{10}$)	--	.0125	.1064	.0458	.1702	.3175[b]
ASI ($Cost^{10}$)	.0125	--	-.0172	.0607	-.0252	.3327[a]
ASI ($Size^{10}$)	.1064	-.0172	--	.0171	.6053[a]	.5457[a]
ASI ($Requirement^{10}$)	.0458	.0607	.0171	--	.2882[b]	.3489[a]
ASI ($Priority^{10}$)	.1702	-.0252	.6053[a]	.2882[b]	--	.7009[a]
ASI (Equal Weights)	.3175[b]	.3327[a]	.5457[a]	.3489[a]	.7009[a]	--

[a] Significant at the .001 level.

[b] Significant at the .01 level.

TABLE 21

First-Term Attrition Severity Index (ASI)
for U. S. Navy Ratings
(1 = least severe; 85 = most severe)

Ranking	Rating	ASI	Ranking	Rating	ASI
1	GSE	3	20	BU	22
2	PM	10	21	CTI	21
3	PH	11	22	IS	21
4	DM	12	23	UT	21
5	CM	12	24	BU	22
6	LI	13	25	GSM	22
7	ML	15	26	ASE	23
8	AC	17	27	DP	23
9	MU	17	28	EO	24
10	DS	17	29	MT	24
11	SW	18	30	CTM	24
12	ASM	19	31	AW	24
13	RP	19	32	IM	25
14	AG	19	33	ABH	25
15	CE	20	34	MN	25
16	JO	20	35	AME	26
17	MR	20	36	BM	26
18	EA	20	37	AZ	27
19	ABF	21	38	DK	28

TABLE 21 (Cont'd)

First-Term Attrition Severity Index (ASI)
for U. S. Navy Ratings
(1 = least severe; 85 = most severe)

Ranking	Rating	ASI	Ranking	Rating	ASI
39	ABE	28	58	PR	37
40	AMH	29	59	STS	37
41	CTA	29	60	AO	37
42	AK	29	61	PN	37
43	AX	30	62	GMM	41
44	AE	30	63	FTG	41
45	AMS	31	64	IC	41
46	AD	31	65	GMG	42
47	CTO	31	66	HT	42
48	GMT	31	67	YN	43
49	EN	31	68	EW	43
50	CTR	32	69	FTM	44
51	CTT	32	70	FTB	45
52	PC	32	71	AT	45
53	SK	32	72	OT	45
54	OM	33	73	TM	46
55	TD	33	74	EM	48
56	QM	34	75	SH	52
57	STG	36	76	ET	56

TABLE 21 (Cont'd)

First-Term Attrition Severity Index (ASI)
for U. S. Navy Ratings
(1 = least severe; 85 = most severe)

Ranking	Rating	ASI	Ranking	Ranking	ASI
77	AQ	58	82	HM	73
78	BT	63	83	OS	74
79	SM	63	84	DT	85
80	MS	67	85	MM	100
81	RM	70			

and patternmaker ratings, received some of the lowest index values. However, in some cases the results deviated substantially from those expected. Groups such as the dental technician and mess management specialist ratings, appeared among those ratings experiencing the highest attrition severity, while the gas turbine system technician (electrical) and data systems technician ratings were among those receiving the lowest index values.

In some instances, deviations from prior expectations may be the result of the manner in which the attributes or factors were developed, while in other cases, they merely may be the result of intuitive misconceptions. In the case of the gas turbine system technician (electrical) rating, a problem may exist due to the manner in which the individual factors were developed. The gas turbine system technician (electrical) occupational specialty is one of the Navy's newest ratings, created in response to a need to man a new class of gas turbine driven ships. The rating-specific measures developed for the rating indicate that the rating is very small in size, has an extremely high survival rate, and is overmanned. Since the rating is very small, the survival functions developed for the rating could contain a substantial upward bias. Additionally, the requirements factor was developed on the basis of current requirements and current inventory. No consideration was given to the fact that the Navy is training and developing gas turbine system technicians in excess of current requirements in anticipation of the addition of several new gas turbine driven ships to the fleet in the next several years.

Although the first-term attrition severity index developed may not provide an entirely accurate estimate of attrition severity for gas turbine system technicians, the extremely high attrition severity value assigned to the dental technician rating may be an accurate representation of attrition severity for the rating. The Navy traditionally has relied heavily upon the priority or importance factor in determining which ratings require attention. Although the dental technician rating was assigned a very low priority value, its values for survival, replacement cost, size, and requirements were very high. Such a situation emphasizes the need to consider several factors in determining the severity of personnel losses on specific ratings, and provides evidence of the usefulness of a multiattribute model in determining attrition severity.

VII. SUMMARY

The purpose of this thesis was to develop a first-term attrition severity index for 85 United States Navy enlisted rating. Five factors or attributes were identified as having a significant effect on rating-specific first-term attrition: 1) survival, 2) replacement cost, 3) size, 4) shortage or excess of requirements, and 5) priority. The survival factor was designed to indicate the magnitude of rating-specific Navy losses through first-term attrition. Measures of the survival attribute were developed through the use of transitional wastage rates. The replacement cost attribute was developed to reflect the cost required to replace an individual in a particular rating who attrites at a specified time of service prior to the completion of his or her first-term of enlistment. Rating-specific measures of replacement cost were developed from data provided in the Navy Enlisted Billet Cost Model. Data on rating-specific survival and replacement cost were not readily available, requiring an independent development of these measures. The size, shortage or excess of requirements, and priority factors represented the Navy's demand for individuals in specific ratings. The size attribute was developed to reflect the size of first-term, rating-specific, personnel inventories; the shortage or excess of requirements attribute provided measures of how well current personnel inventories in specific ratings matched billet requirements; and the priority factor indicated the importance of particular ratings to the Navy in meeting its national defense role in times of international conflict.

The five factors developed were provided as input to a multiplicative multiattribute model to derive an index of first-term attrition severity for the 85 ratings considered. When all factors were equally weighted within the model, the results provided were in general those expected. Occupational specialties, such as the boiler technician, machinist's mate, operations specialist, and fire control technician (ballistic missile fire control) ratings, were among those receiving the highest index values, while the photographer's mate, lithographer, musician, and patternmaker ratings received some of the lowest index values. Analysis of the results indicated that no single factor could be used to assess first-term attrition severity, and provided evidence of a need to use a multiattribute model in determining first-term attrition severity among Navy ratings.

A first-term attrition severity index is of potential value to the Navy in reducing the adverse effect of the loss of personnel through attrition by providing an empirical basis for assigning scarce manpower resources to the ratings identified as experiencing the most severe effects of first-term attrition. The use of the index in conjunction with other decision support models could be of significant value to the Navy in minimizing the total impact of personnel losses from the organization.

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